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Diseases of Small Grains

R. S. Kirby

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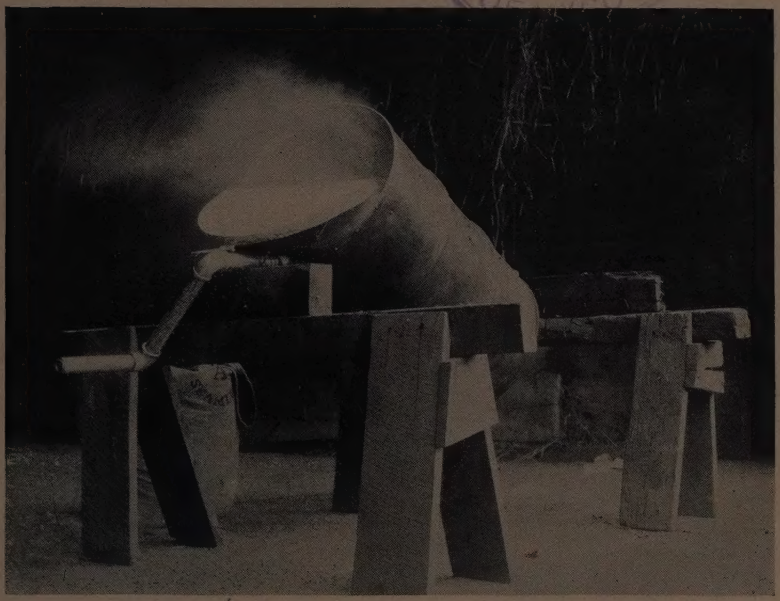

The double-acting drum used for treating seed with dry fungicides

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DISEASES OF SMALL GRAINS

R. S. KIRBY[1]

Small grains are subject to numerous diseases which may materially reduce the yield and may impair the quality of the crops. Often, such losses, because of their obscurity and of the insidious nature of the disease, are overlooked by growers. Proper attention to control measures will usually aid in increasing the yield and in reducing the cost of production. This bulletin is prepared to acquaint grain growers with the various diseases affecting their crops and to give them information about the measures that may be applied in controlling these diseases.

WHEAT

STINKING SMUT, OR BUNT, OF WHEAT

(Caused by *Tilletia laevis*)

Previous to 1924, stinking smut, or bunt, was present in less than 10 per cent of the wheat fields of New York. In 1925 there occurred the most serious outbreak of this smut on record. With the continued practice of delaying the planting of wheat in order to avoid the Hessian fly, it is possible that this smut may become one of the most serious of wheat diseases. Usually only small amounts are found, but, if treatments are neglected, the amount of smut may rapidly increase. As high as 60 per cent of the heads in a given field have been found to be affected.

Stinking smut gets its name from the characteristic odor of the smutted grain, which resembles decaying fish. The loss due to this smut is not confined to the destruction of the affected seed. An additional loss results from the odor imparted to flour made from smutted grain. Wheat contaminated with smut is subject to "smut dockage" on the market. Further, the feeding of quantities of smutted grain to animals may in some cases cause injury.

All varieties of wheat commonly grown in New York are susceptible to this smut. There is, however, a wide range of difference in their susceptibility. Under optimum conditions for infection, the percentage of disease ranges from 20 to 60 in the following varieties which are listed in the order of their resistance: Junior No. 6 (Gold Coin), Pennsylvania 44, Fultz, Red Wave, Fulhio, Trumbull, Dawson, Honor, Fulcaster, Red Rock,

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Leap, and Forward. Under New York conditions the Kanred or the Turkey types, wheats which are extensively grown in the Middle West and the West, were found to be nearly twice as resistant to this smut as were any of the foregoing varieties.

Symptoms

The first symptom of the disease appears soon after the emergence of the head. At this time the smutted heads are blue-green in color in contrast to the yellowish green cast of healthy ones. At time of blooming, the affected heads are slimmer and are bluer in color than healthy heads, and the anthers which are shriveled fail to emerge from the glumes (figure 1). At maturity, infected heads appear dark green to bluish in contrast to the golden yellow of the healthy heads. The smutted heads are more erect than the healthy ones which often bend more or less from their own weight. An examination of a smutted head shows that the kernels are shorter and plumper than in normal wheat (figure 2). The tough coat of the affected kernels surrounds a dark dusty-like mass of smut spores which have a fetid odor perceptible to the leeward of an infested field and in smutted grain confined in sacks or bins. Affected kernels are called *smut balls*.

FIGURE 1. STINKING SMUT OF WHEAT

Left, two affected heads; right, healthy head; at blooming time. Note the absence of anthers on the smutted heads

Cause

The fungus causing this disease passes from one wheat crop to another as spores (chlamydospores). From 1,000,000 to 4,000,000 of these are formed in each kernel of smutty wheat. In a dry protected place like a grain bin the spores in the smut balls may remain viable from eight to twelve years and those spores which have escaped from the ball may live from two to three years.

The spores are scattered when the coat of the smut ball is ruptured during harvesting, threshing, or seeding. Some adhere to the surface of the healthy kernels with which they come in contact. Here they remain dormant until the wheat seed is planted

FIGURE 2. STINKING SMUT OF WHEAT
Left, healthy head and kernels; right, two smutted heads and smut balls

and until the conditions of temperature and moisture are suitable for their development. The spore germinates by means of a short tube bearing secondary spores, each of which may send out a delicate root-like thread capable of entering the growing shoot of the wheat seedling at any time before it reaches the surface of the ground. After the fungus gains entrance into the growing shoot of the seedling, it grows upward within the stalk, doing but little damage until the flower of the wheat is formed. The fungus, in most cases, enters every flower on a head and there produces its spores which completely fill the kernel before it matures.

Spores scattered on the soil during harvest and threshing may retain their vitality, especially in the intact smut ball, from one to several months. On germination, these produce a saprophytic growth that may live in the soil from twenty to fifty days. If wheat follows smutty wheat or is planted in soil over which spores were scattered during threshing, some infection may take place from this fungus in the soil.

The smut spores germinate in a fairly damp soil and bring about infection in increasing amounts as the temperature drops from 68° to 41° F. Consequently, this smut is less likely to be destructive when wheat is planted early rather than late in the autumn, since the soil temperature is then about 68° F. and the soil is drier. However, late planting in this State is advised in order to avoid infestation of the Hessian fly. Therefore, seed treatment should be combined with late planting if both pests are to be avoided, but the planting should be made as soon as possible after the danger of the Hessian fly has passed.

Seed wheat from badly smutted fields, as those having more than 10 per cent of affected heads, should not be used for planting. Even when such seed is treated, perfect control cannot usually be obtained.

Control

Since this smut passes from one crop to another largely as smut balls or as spores adhering to the coat of the seed, and to a lesser extent in the soil, a control measure to be successful must remove the smut balls, kill the spores adhering to the seed, and protect the seed from reinoculation and the young seedlings from infection from the fungus in the soil. The first steps in any treatment should be to run the seed over a fanning mill to remove as many smut balls as possible and to avoid soil infection by crop rotation.

Both the copper-carbonate and the formaldehyde treatments will kill the spores adhering to the seed, and the copper-carbonate treatment will also protect the seed from reinoculation and from the fungus in the soil.

Copper-carbonate treatment

The copper-carbonate treatment has the following additional advantages over the formaldehyde treatment:

1. It eliminates seed injury and retarded growth, with an improvement in germination over that of untreated seed. This seems to result in better stands of wheat and slightly increased yields which more than pay the difference in cost between the two treatments.

2. It requires less labor than the formaldehyde treatment and eliminates wetting the seed and the subsequent drying.

3. Since the dust may remain indefinitely on the seed without causing injury, the seed may be treated at any time before planting.

4. It protects the treated grain from weevils, beetles, and mice.

These advantages are offset somewhat by the fact that grain treated with copper carbonate is poisonous and must not be fed to livestock. Furthermore, such grain even when thoroly scoured is unfit for bread flour. The dust is also a moderate poison to men when breathed. There-

fore in treating, the work should be done in the open and a respirator, a wet sponge, or a cloth should be worn over the mouth and the nose.

If allowed to stand and become moist, copper carbonate from the treated seed will cake and harden in the seed box and around the moving parts of the feed mechanism of the drill so that these parts will be locked in place, teeth will be stripped from the feed gears, and the drill will be rendered useless for the time being if it is started while in this condition. The seed feeds should always be thoroly cleaned at the end of the day. Treated grain does not pass so readily thru the drill as does untreated grain, often necessitating opening the drill from one-tenth to one-third more, or using the oat side.

Copper-carbonate dust is effective only when every kernel of wheat is thoroly coated with the dust. This coating can be most effectively applied in a specially constructed apparatus like the double-acting drum (figure 3) or a commercial treating machine. Attempts to mix the wheat and the dust by shoveling or even to mix them in makeshift outfits usually result in incomplete control. It is recommended, therefore, that in using the copper-carbonate treatment a 30-gallon double-acting drum be constructed or a commercial machine be purchased.

Amount and kind of copper carbonate to use

Two and one-half ounces of copper-carbonate dust should be used for each bushel of wheat. If more is used, it is wasted and may give trouble when the seed is drilled. The use of less than two and one-half ounces may result in incomplete control. Best control is obtained with pure copper-carbonate dust that is fine enough to pass thru a 200-mesh screen.

Method of treating wheat

The machine made from the 30-gallon barrel will treat one bushel of wheat at a time and two men can treat from twenty to forty bushels in an hour. One should proceed as follows:

1. Put one bushel of wheat into the machine.
2. Scatter two and one-half ounces of the copper-carbonate dust over the surface of the wheat.
3. Close and fasten the door of the container.
4. Turn the drum thru at least forty complete revolutions at a speed of thirty revolutions a minute. If the drum is turned too fast or too slow, the wheat will be poorly coated.
5. Open the drum and pour the wheat into a container placed under the machine, or lift the drum and pour the wheat directly into grain sacks.
6. The wheat may be planted at once or may be stored for an indefinite period without danger of seed injury from the dust.

Directions for making the 30-gallon double-acting drum

The treating drum (figure 3) here described is a dust-tight apparatus which thoroly mixes the wheat and the dust by throwing the wheat against a mixing board as it goes from end to end of the drum. Greater convenience in filling and emptying the container is obtained by having the opening at the end of the drum.

The machine is conveniently made from an old 30-gallon steel oil drum (figure 4).

One-half of one head of the drum is cut out. A strip of board one inch thick, six inches wide, and the proper length to fit snugly against the sides of the drum, is bolted to the remaining half of the steel head so that about one-half inch of the edge of the steel head extends beyond the board. A wooden head of such size and shape as to fit snugly over the open half of the drum head is then cut. This is hinged to the six-inch wooden strip so that the wooden half of the head will open. This head should be dust-tight. If it does not fit snugly, a strip of rubber cut from an old inner tire-tube may be nailed around the edge. A hinged hasp is used to hold the door shut, and it is so attached that the door will be forced tightly against the edge of the drum when closed.

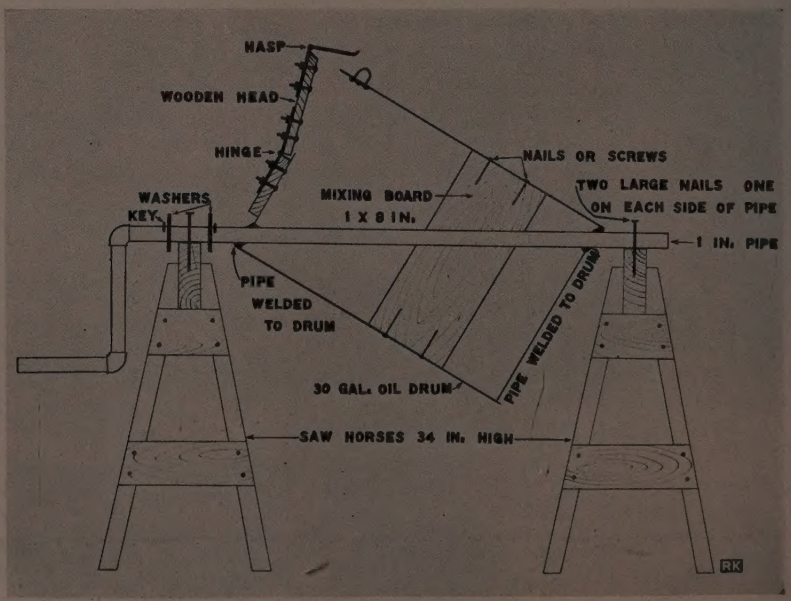

FIGURE 3. APPARATUS FOR TREATING GRAIN WITH DRY FUNGICIDE, SHOWING DETAILS OF CONSTRUCTION

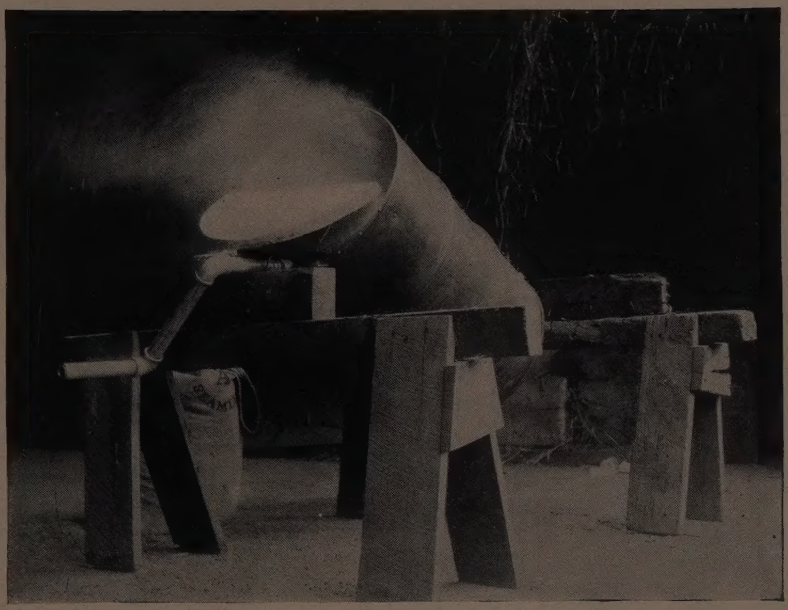

FIGURE 4. A DOUBLE-ACTING TREATING MACHINE USED IN TREATING SEED WITH DRY FUNGICIDES

The axle consists of a piece of one-inch pipe, fifty inches long, which passes diagonally thru the drum (figure 3). It extends beyond both ends of the drum for about eight inches. The drum is best anchored to the axle by being electrically welded to it. If it is impossible to get this welding done, secure the axle to the drum by passing bolts thru holes drilled in the barrel and the axle.

The crank consists of two elbows and two ten-inch pieces of one-inch pipe which are screwed to the axle as shown in figure 3.

A mixing board is essential to the thoro mixing of the dust and the grain. This consists of a 1-inch by 8-inch board which is placed across the inside of the drum about two-thirds of the way back from the opening and at right angles to the straight side of the wooden door. This board is held in place by screws or nails passing thru the side of the drum and into the ends of the board.

To keep the drum from sliding in the bearings, two washers are placed over the axle at the crank end and are held in place by cotter keys passing thru a hole drilled in the axle.

The drum should be turned on a level axis. This can best be done by placing the drum between two sawhorses. The sawhorses should be not less than thirty-four inches high for greatest efficiency.

Bearings for the axle to turn in can be made by driving two large nails into the sawhorse, one on each side of the axle. A little axle or cup grease will provide lubrication. This treating machine can be made of a 30- to 50-gallon wooden barrel or even a 50-gallon oil drum. However, the 30-gallon outfits turn easier and are just as efficient. A steel drum is preferred to a wooden barrel since the drum will not stave in.

The cost of building this apparatus has been found to be from $1.25 to $7. A garage man supplied all the material and built the machine here pictured (figure 3) at a charge of $6.15 to the purchaser.

Formaldehyde treatment

For those who object to treating their seed with a poison like copper carbonate or where the equipment and the material for treating the wheat is not available, the formaldehyde treatment is recommended.

The wheat is treated as follows:

Pour into a washtub or any large shallow container until it is two-thirds full, a solution of formaldehyde made by diluting one pint of 40-per-cent formaldehyde in forty-eight gallons of water. Pour the seed into the tub and stir thoroly. Skim off all smut balls, chaff, and light kernels that rise to the surface during the treatment. Remove the grain after it has been in the solution for ten minutes and spread it out to dry, after which it is ready to sow.

Wheat should be planted within a few days after treatment with formaldehyde, since if stored for any length of time, its vitality may be reduced.

LOOSE SMUT OF WHEAT

(Caused by *Ustilago tritici*)

Loose smut is present in nearly every wheat field and causes a greater loss to the growers of certain varieties than any other wheat disease in New York. During the past six years there has been an average loss of more than 1.5 per cent; on susceptible varieties it has averaged about 3 per cent. One field was observed in 1921 in which 26 per cent of the heads were destroyed.

Of the varieties of wheat, Junior No. 6 (Gold Coin) and Leap are apparently very resistant to this smut. Seldom are more than a few smutted heads found in any fields of these varieties. Forward, while showing a certain degree of resistance, is more susceptible than the first two varieties mentioned. Dawson (Dawson Golden Chaff), Honor, Red Rock, Pennsyl-

vania 44, and Fulcaster, have shown, on the average, at least 3 per cent of smut and, therefore, cannot be classed as resistant.

Symptoms

The first evidence of loose smut appears as soon as the wheat head is thrust beyond the leaf sheath (figure 5). Affected heads consist of an olive-brown smut mass which has replaced all of the flowers and the glumes. The whole head thus becomes a black powdery smut mass which is soon blown away, leaving the naked rachis that easily escapes observation at harvesting.

Usually all heads on a plant are destroyed but in rare cases several heads or parts of individual heads may be normal. The smut is ordinarily confined to the head, rarely occurring on the leaves as long dark streaks.

FIGURE 5. LOOSE SMUT OF WHEAT

Cause

The dusty masses are the spores of the fungus that live as a parasite upon the wheat. These spores, blown about at the time the grain is in bloom, fall upon wheat flowers where they at once germinate and send a germ tube into the young kernels. By the time the infected kernels mature, the fungous growth has established itself in the embryo. It remains there in a dormant condition until the seed, after being sown, starts to grow, when it continues its growth within the stalk and into the developing flower which it replaces by its own spore mass.

There is some variation in the amount of smut present from year to year. This variation is influenced by the weather conditions at planting and flowering time. Fair weather and gentle breezes at flowering time promote dissemination of the spores and smut infection. Rains at this time decrease the amount of smut infection by washing the spores to the ground, thus keeping them from reaching other wheat heads. A higher temperature may be required for the growth of the fungus than for the germination of the wheat, so that infected seed sown early will result in

larger percentages of smutted heads than will later sowings. Smut is worse when the plants are grown on poor soil.

Control

Since such varieties of wheat as Junior No. 6, Leap, and to a lesser degree Forward, are resistant to smut, the use of these varieties where practicable is a desirable method of control. The amount of smut may be somewhat reduced by planting wheat late in the fall, but this cannot be depended upon to give satisfactory control.

Any seed treatment to be effective must destroy the fungus which lives within infected kernels. The most practical method known at the present time is the modified hot-water treatment. The treatment is advisable only when live steam, large treatment tanks, and standardized thermometers are used to maintain the correct temperature. Growers desiring to control loose smut and having complete equipment should treat sufficient seed to plant an entire field. The planting should be as far removed as practicable from fields where untreated wheat is planted. The seed obtained from this field may then be distributed as free from loose smut, since only a small amount of smut may be expected to show up in the second crop if the treatment has been made properly.

Three containers are needed in making this treatment. Each should be partly filled with water, one of them with cold water, another with water held at a temperature of 120°F., and the third with water kept, as nearly as possible, at a temperature of 129°F. while the treatment is being made. The temperature in the second and the third containers is best maintained by live steam conducted into the containers thru a hose or pipe. The water may be held at the required temperature by regulating the flow of steam.

The seed to be treated should first be run thru a fanning mill to remove light diseased kernels. It is then placed in coarse two-bushel burlap sacks. Not more than two pecks should be placed in a sack which should be tied at the top. The sacks of seed are soaked in the cold water of the first container for not less than four or more than six hours. The sacks are then removed and allowed to drain, after which they are immersed from one to two minutes in the second container in order to warm the seed so that it will not materially reduce the temperature of the water in the third container. The sack of wheat is then quickly removed from the second container and placed for ten minutes in the third in which water is kept at 129°F. If the temperature in the third container should rise above or fall below 129°F., the time of immersion must be diminished or increased accordingly. For example, the immersion should continue for fifteen minutes at 126°F. or for eight minutes at 130°F. Under no circumstances

should the temperature rise above 131°F., since at higher temperatures the seed is killed. It should not fall below 124°F., for in such a case, the fungus will not be destroyed. While treatment is going on, the sack should be agitated so that the seed in the center may become quickly heated to the required temperature. If more than two pecks are placed in a sack, the seed in the center will not be treated adequately. After treatment in the third container for the required length of time, the seed should be removed promptly and plunged into cold water or spread out on a floor to prevent further heating. It may be dried by spreading it out in layers not more than two inches deep on a clean barn floor, or on canvas, and by shoveling and raking it from time to time. Before being planted, treated seed should be dried until it has approximated its pre-treatment size.

The vitality of the wheat is usually reduced by the hot-water treatment. Kernels with broken seed coats are especially subject to injury. The degree of injury depends on the percentage of broken seed coats and the care that is given during treatment in keeping time and temperature within the prescribed limits. The amount of injury can be determined by running a germination test in soil. Any moderate injury can be offset by increasing the rate of seeding to compensate for the reduced vitality.

The hot-water treatment, in addition to eliminating the loose smut, will also reduce the amount of other seed-borne diseases, such as scab and anthracnose.

FLAG SMUT OF WHEAT

(Caused by *Urocystis tritici*)

Flag smut, a destructive disease of wheat, has never been found in New York but does occur in Illinois, Missouri, and Kansas. It is described here because there is a possibility of its being introduced; therefore, growers should watch for it. Dawson and Leap have been found to be susceptible, while Forward, Junior No. 6 (Gold Coin), Red Rock, and Fulcaster, are resistant.

Cause

Flag smut is caused by the fungus *Urocystis tritici*. The black lines in the leaves (figure 6) consist of masses of spores of the smut fungus. Prior to the emergence of the seedling, or shortly thereafter, infection takes place from spores carried either on the seed or on the infected plant material. It is also possible for infection to result from spores in the soil to which they may be carried in various ways.

Control

Only varieties that are highly resistant should be planted in infested areas. As the wheat comes from the thresher, it should be treated with

FIGURE 6. WHEAT LEAVES AFFECTED WITH FLAG SMUT

Photographed by the Office of Cereal Investigations, United States Department of Agriculture

formaldehyde. Wheat should never be sown two years in succession on the same ground, and seed from healthy fields only should be used. Burning the straw from infected fields will help to control the smut. However, this is seldom practiced.

STEM RUST OF WHEAT

(Caused by *Puccinia graminis tritici*)

Stem rust, which is considered to be the most destructive disease in the western grain-growing sections, is present only to a slight extent in New York. Observations indicate that ordinarily the loss from this disease is less than 0.1 per cent, and that it is present in only a small percentage of the wheat fields. In 1918 there was an unusually large amount of stem rust present in the State, but even then the loss was estimated at less than 1 per cent.

One stage in the development of this rust occurs on the common barberry (*Berberis vulgaris*).

Symptoms

On the barberry.— The disease makes its appearance on the barberry in New York about the first week in May. At that time small yellowish spots appear on the upper surface of the barberry leaves, followed by the development of slightly larger elevations on the lower surface. Within these spots there soon develops tiny golden cups filled with a yellowish powder. This constitutes the cluster-cup stage of the rust (figure 7).

On wheat.— This rust appears in New York during the first two weeks of July or only shortly before the wheat matures. It shows beneath

the epidermis as elongated brown pustules (figure 8) on the stem, the leaf sheaths, the head, and the leaves, the stem usually being first and most severely affected (figure 9). The pustules may be one-fourth inch or more in length and usually coalesce. The epidermis is soon ruptured. Fragments of it adhere to the sides and especially to the ends of the pustules, and a brick-red powder is exposed. This constitutes the red-rust stage of the disease.

As the season advances the contents of the pustules become black in color. These black pustules, known as the *black-rust* stage of the disease, remain on the straw and stubble thruout the winter.

FIGURE 7. AECIAL STAGE OF WHEAT STEM RUST ON THE BARBERRY

Photographed by the Office of Cereal Investigations, United States Department of Agriculture

Cause

In a climate like that of New York, the fungus causing the stem rusts of cereals is unable to complete its life cycle upon the cereals alone, but requires another plant, the common barberry, for its complete development. The fungus is highly specialized; that is to say, it consists of a number of distinct forms looking, even under the microscope, almost exactly alike and all capable of attacking the common barberry. Each form also attacks certain cereals and wild grasses, some of which may be the same and some different from those affected by the other forms.

The forms are as follows:

1. Wheat stem rust (*Puccinia graminis tritici*) attacks wheat, barley, and numerous wild grasses. In New York this form of rust is seldom found on the barberry or on any of the grass hosts as, for example, lyme grass (Elymus sp.) and cheat (Bromus sp.) which are relatively scarce and seldom found in close proximity to the common barberry. This condition is different from that in the Central West where there are more grass hosts. One of these hosts, squirrel tail grass, *Hordeum jubatum*, is seldom found in New York but is found abundantly in the West where it is usually heavily rusted.

2. Rye stem rust (*Puccinia graminis secalis*) affects rye, barley, and numerous wild grasses. This form of rust rarely attacks wheat or oats.

FIGURE 8. WHEAT STEM RUST ON GLUMES AND AWNS
Photographed by the Office of Cereal Investigations, United States Department of Agriculture

In New York this form is commonly found on barberry and on quack grass. The rust appears on this grass during the second week in June and on rye about a week later, when these are growing near the barberry.

3. Oat stem rust (*Puccinia graminis avenae*) affects oats and several species of wild grasses. This form of rust is seldom, if ever, found on wheat, rye, barley, and the grasses attacked by the wheat and rye forms of stem rust. In New York oat stem rust occurs commonly on the barberry and on orchard grass. It appears on this grass about the middle of June and on oats during the first two weeks in July, when they are growing near the barberry.

4. Red-top rust (*Puccinia graminis agrostis*) affects red top and several other species of wild grass. This form practically never affects cereals

or the common grasses attacked by the other rust forms. In New York this rust is common on the barberry and the red top.

A field of rye may have considerable stem rust, while a neighboring field of wheat is free from infection; or a field of wheat may be considerably affected, while a field of rye near-by is free from the infection. This is due simply to the fact that the form of stem rust affecting rye is different from the one affecting wheat. Specialization of the rust fungus is not restricted to forms that occur on different kinds of cereals and grasses. Each form consists of a number of subforms or physiologic forms each of which varies in the degree of infection it is able to produce on the different varieties of its cereal hosts. The wheat form of stem rust is made up of approximately forty subforms. The use of resistant varieties as a control measure involves getting varieties of cereals resistant to all the subforms or at least to those forms commonly present in the locality in which the cereal is grown.

FIGURE 9. STEM RUST OF WHEAT

All forms of stem rust in New York have a similar life history. They pass the winter in the black-rust, or telial, stage on the stems and leaves of affected cereals or grasses. The black-rust stage consists in part of thick-walled black spores, called *teliospores*, which remain dormant until spring. With the advent of warm, rainy weather they germinate and produce thin-walled secondary spores called *basidiospores*. These are easily blown about for short distances. On coming in contact with barberry leaves, they may infect them and produce the cluster-cup stage already described. This usually takes place if affected grasses are growing near-by. Aeciospores are formed in the tiny cluster cups on the undersides of the barberry leaves. These spores, at maturity, are blown about and may reach susceptible grains and grasses growing within a radius of about one-half a mile. Infection of these plants by the aeciospores results in the development on them of the red-rust stage of the fungus. The red-rust spores, or *urediniospores*, produced on the rusted plants, after reaching maturity, are disseminated by wind and

splashing rain to other grasses and grains, where they may again produce the red-rust stage. Infection from the urediniospores may be repeated from every eight to fourteen days thruout the summer. As the cereals and grasses approach maturity the black, or telial, stage of the rust replaces the red-rust stage in the affected areas, thus completing the life history.

The regular practice of growers in following a long rotation and the absence of most of the more susceptible wild-grass hosts, results in a situation in New York unfavorable for the infection of the barberry with the wheat form of rust. However, when this infection does take place, the lack of susceptible grasses near the barberry greatly decreases the chances of the rust reaching the wheat in time to cause injury. The wheat stem rust present in New York is thought to result largely from red-rust spores carried by the wind either from the West, where the barberries are commonly heavily infected and play an important part in the life cycle of the fungus, or from the southern part of the United States where the fungus lives over the winter on cereals and grasses.

Control

Since it has been found that the barberries in New York do not play so important a rôle in the spread of the wheat-stem rust as they do in the West, barberry eradication has not been advocated except in specific instances. If there are serious outbreaks of wheat stem rust in a certain locality for several years, a search should be made to determine whether infected barberries are present and, if so, they shoud be removed or killed by chemicals. The common green-and-purple-leaved barberries with the spiney-edged leaves, and with its berries borne in clusters, are the ones that serve as alternate hosts for the rust fungus. The Japanese barberry, a lower-growing shrub having smooth-edged leaves and its berries borne singly or in pairs, is not affected by this rust and need not be destroyed as a measure of control.

The planting of early maturing varieties of wheat lessens the danger of loss due to stem rust since such varieties ripen before the stem rust causes serious damage.

Stem rust is not carried in the seed, and seed treatment in no way influences the amount of rust.

ORANGE LEAF RUST OF WHEAT

(Caused by *Puccinia triticina*)

Orange leaf rust is the most common and seemingly the most destructive disease of wheat in New York. It is estimated to cause a loss which

varies from 1 to 3 per cent. The amount of rust and the subsequent loss each year depends on the relative prevalence of rainy or foggy weather which favors infection.

FIGURE 10. LEAF RUST ON WHEAT LEAVES AND STEM

Leaf rust reduces the yield of the wheat by affecting the leaves which, in severe cases, are killed prematurely. Since the leaves manufacture the food which is stored in the seeds, their early death results in a reduction in the number and the size of the kernels. Wheat is the only cereal usually affected by orange leaf rust.

Symptoms

This rust can be found on wheat at all times during the year. It is confined almost wholly to the leaves (figure 10), rarely affecting the stems and heads. It appears as small oval spots of a bright orange color which later have a powdery appearance. The spots, or pustules, are found more commonly on the undersides of the leaves. As the wheat matures, the orange-colored pustules are replaced by brownish black patches which usually remain covered by the epidermis.

Since leaf and stem rusts often are difficult to tell apart in the field, the accompanying table giving the chief differentiating characters may be of help.

Stem rust	Leaf rust
1. Pustules are mainly on the stems.	1. Pustules are mainly on the leaves.
2. The red-stage pustules are narrow and long, run parallel with the veins, gradually enlarge, and may coalesce, and on rupturing they leave adhering fragments of epidermis, especially at the ends of the pustule. Their color is brick-brown to brown, gradually becoming darker as the black spores form.	2. The red-stage pustules are small, about the size of a pinhead, oval or round, irregularly scattered over the leaf, seldom run together, and on rupturing they leave a very inconspicuous fringe of epidermis around them. Their color is bright orange-yellow.
3. The black-stage pustules are like the red pustules, except that they contain a cushion of black spores.	3. The black-stage pustules are very inconspicuous, flattened, and covered by the epidermis. The color is black.
4. In addition to wheat it also affects barley and several wild grasses. The alternate stage is on the common barberry.	4. Ordinarily it affects only wheat. The alternate stage is on meadow rue (Thalictrum sp.).

Cause

The leaf-rust fungus passes the winter as spores or as mycelium inside the wheat leaves. It propagates itself from year to year by forming red-rust spores (urediniospores) which, when mature, may be blown or washed to other parts of the plant or to other plants. Under the proper moisture and temperature conditions, the spores germinate and infect the wheat. This cycle of spore formation, dissemination, and infection is repeated

continuously thruout the growing season. The fungus may, under favorable conditions, form new red-rust spores in from eight to fourteen days after infection, while during unfavorable conditions the formation of these spores may be delayed from one to several months.

The black spores have infected meadow rue (Thalictrum sp.) in greenhouse cultures. This stage of the rust, however, has never been found under natural conditions. The species of meadow rue that are found in this State are resistant, and it is doubtful whether they could figure very largely in the spread of this rust.

Control

No method of control can yet be advised for the East. Kanred, a variety of hard red winter wheat grown in the Middle West, is resistant but this variety is not adapted to New York conditions.

SCAB, OR FUSARIUM BLIGHT, OF WHEAT

(Caused by *Gibberella saubinetii*)

Scab, or Fusarium blight, of wheat occurs practically wherever wheat is grown. It causes a considerable loss in many sections of the United States, especially in the Central West where, in wet years, it is often the most destructive disease of wheat. In New York during wet years, such as those of 1919 and 1922, the loss averages from 1 to 2 per cent for the head-blight stage and only slightly lower for the seedling blight. During years in which there is a normal rainfall at the time the grain is heading, the loss is comparatively small. In the spring-wheat-growing area along the St. Lawrence River, the disease results in an average loss of more than 2 per cent.

In addition to wheat, the disease affects corn, rye, barley, oats, and various grasses among which are blue grass, quack grass, cheat, and foxtail.

Symptoms

This disease may cause either a blight of the young seedlings or a blast of the head which is referred to as scab.

On young seedlings.— The disease of seedlings is often overlooked on account of its inconspicuousness. Wheat stands may be reduced by having many of the kernels killed or the plants so weakened that they are unable to reach the surface of the ground. Other seedlings may be killed by the time the first or second leaf is produced. These infected seedlings are first noted as being stunted. Later they turn yellow, and on examination their roots are found to be rotted and of a reddish brown color. The pink-colored mycelium of the causal fungus may form a web-like mass over

them. Other seedlings may have only parts of the roots rotted. This reduces the tillering ability of the plant so that it is often able to send up only one stem, which produces at most a single small head. All gradations of this stunting and blighting may occur.

FIGURE 11. SCAB OF WHEAT

Left, healthy head; center, partially scabbed; right, entirely scabbed head. (Photographed by the Office of Cereal Investigations, United States Department of Agriculture)

On the heads.— The most characteristic and conspicuous symptoms of this disease appear on the heads soon after flowering. One or more spikelets in any part of the head may be affected (figure 11). The diseased spikelets appear as if they were prematurely ripened, since they lose their

green color, die, and turn light yellow. The disease may spread from affected spikelets into the central stem and cause the death of that part of the head above this point. A mass of light pink or salmon-colored spores and mycelium may be formed along the edge of the glumes of the affected spikelets. Later, the minute dark-blue or black spore cases of the pathogene may be formed on the same glumes. The kernels become bleached and in many instances are severely shriveled (figure 12).

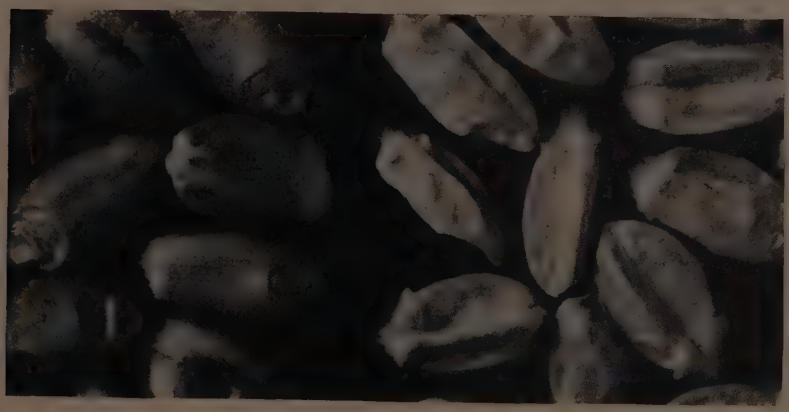

FIGURE 12. SCAB OF WHEAT

Right, scabbed kernels; left, healthy kernels. (Photographed by the Office of Cereal Investigations, United States Department of Agriculture)

Cause

Practically all of the seedling and head blight in this State is caused by the fungus *Gibberella saubinetii*. Several other species of Fusaria sometimes cause a similar blight of seedlings and heads. However, the slight importance of these other pathogenes does not warrant their discussion here.

Seedling blight is caused by the mycelium of the pathogene coming from affected seed where it may live for several years within the seed, or from the soil where it lives for at least a year on decaying organic matter. The fungus may spread from an infected seedling to healthy ones near-by. Head and seedling blight are brought about by separate infections, as the fungus can not grow up or down the stem.

The blighted, or scabbed, heads are caused by infections from either the summer or the winter type of spores. The summer spores are produced in large numbers on all parts of the blighted seedlings, bits of old wheat or cornstalks, and blighted heads. The winter spores, or the type produced in the minute black fruiting bodies which may be formed on all parts of

affected plants, are discharged in vast numbers during wet weather. These, as well as the summer spores, are easily blown or spattered about in rain drops. If they reach the head during favorable weather, they are able to infect the spikelets and cause the disease.

If during flowering time the weather is warm and muggy, with heavy dews or gentle rains, as in 1922, the amount of head blight, or scab, rapidly increases and heavy losses may result. Dry weather during flowering time is unfavorable for the germination of the spores and the growth of the fungus. When such weather prevails, as in 1921, a crop almost free from scab is produced.

Control

This disease is more difficult to control than the smuts but the losses caused by it can be greatly reduced by taking certain precautions.

The worst outbreaks of seedling and head blight have occurred where wheat followed corn on the same land. Where this has been practiced, it has not been uncommon to find 25 per cent of seedling blight and 80 per cent of head blight. In opposition to this condition, parts of the same wheat fields growing on land previously planted to potatoes or crops other than cereals, showed practically no seedling blight and less than 8 per cent of head blight.

If wheat is to follow wheat or corn, as much as possible of all crop refuse should be burned and the remainder plowed under before planting time. This lessens the amount of inoculum by removing the material on which the pathogene can live.

Seed should be obtained from the cleanest known fields. All seed should be cleaned and graded in order to remove all diseased or shriveled kernels, as the fungus seldom lives in the plump ones.

Winter wheat should be sown late and spring wheat early when the ground is below 60°F., a temperature below which the wheat seedlings grow better than at higher temperatures and the organism does not attack them so readily. Under these conditions moderately infected kernels may even produce good plants.

TAKE-ALL OF WHEAT

(Caused by *Ophiobolus cariceti*)

Take-all is a serious disease of winter wheat in the countries where it occurs. In the west-central part of New York, it is present in about 75 per cent of the winter-wheat fields. Within the infested area it causes an average loss of from 0.5 to 2 per cent. Its importance varies from year to year, depending on climatic conditions.

In addition to wheat, this disease commonly occurs on the following wild grasses: quack, cheat, red top, and Canada blue grass. It is also found on rye, barley, and timothy.

Symptoms

Take-all affects the roots, culms, leaves, and heads of its host plants.

On the roots. — During the late winter and early spring, the disease becomes evident as brown spots on roots of winter wheat. These lesions (figure 13) increase in number during the warm spring weather, with the result that by the time the plant reaches the jointing stage most of the roots of badly infected plants are brown and dead. The dead roots are so weak that a slight pull will sever the plant at the crown. A number of short fine rootlets are produced on the layer roots near the crown and give them a thick woolly appearance. On removing a plant from the soil, it is found that considerable soil clings to these rootlets, giving the root system a characteristic clubbed appearance. A blighting of young seedlings, observed in greenhouse cultures, may occur under field conditions.

FIGURE 13. BASE OF WHEAT PLANT SHOWING TAKE-ALL LESIONS ON STEMS AND ROOTS

On the stems and heads.— The first symptoms on the parts above ground appear after the plants have reached the jointing stage and are from eight to ten inches high. They have been observed in New York as early as May 22. The plants become yellow and those most severely affected soon die. By flowering time definite areas of diseased plants appear in the fields. These areas, which are usually circular in shape, contain from one to many plants and sometimes attain a diameter of fifteen or more feet. The disease may occur for several feet along the drill rows. Those in the center of large areas either die and become ashy

gray or are dwarfed to a few inches in height. Most of the diseased plants develop, on the average, but a single head and are dead by flowering time. Even those affected plants that survive until after flowering produce grain so badly shriveled as to be worthless. During seasons when there is considerable wet weather before harvest, the leaves, the stems, and the heads of the diseased plants become sooty black from saprophytic molds growing on them.

There is a dark-brown or black zone at the base of the diseased stems. The lower leaf sheaths are discolored and a thin black gelatin-like plate may be found between the stem and the inner leaf sheath. Minute black specks which are the beaks of the spore cases of the pathogene are found in varying numbers on the discolored base of the plant.

Cause

The cause of take-all is a parasitic fungus which is able to penetrate the epidermis of the young roots. Once inside the roots, the mycelium of the fungus penetrates into the crown of the plant and thence into the other roots, killing most of those invaded by it. It is unable to grow up the stem of the host to any great distance, the death of the upper portions being due to the diseased condition of the roots and the lower parts of the stalks.

The blackened condition at the base of the stalks is due to the presence there of numerous, thickened, brown, mycelial strands. In these blackened tissues of the stem and roots are formed tiny black spore cases (perithecia) which appear to the unaided eye as minute black specks. In these spore cases are produced numerous winter spores. These spores gradually mature during a period of several months, some spores remaining alive for as long as nine months.

During harvest pieces of straw containing these spore cases may be widely scattered. The perithecia, or spore cases, may be blown to other fields or may be carried there on affected straw contained in manure applied as a top-dressing. They may be distributed on very small bits of straw mixed with uncleaned seed.

When these spore cases reach the ground or are subjected to moist conditions elsewhere, the spores within are gradually pushed out and are washed into the soil. The spores are very sensitive to drying and would doubtless be killed during wind dissemination unless they were carried inside their cases on straw or with infested soil. Under favorable conditions, the spores germinate and produce a mycelium which can extend for only a few inches in the soil. Whenever this mycelium comes in contact with the roots of any of the susceptible cereals or grasses, it penetrates the epidermis and continues its growth within the tissues.

Perennial grass weeds, such as quack grass, are susceptible to attack but are not so seriously affected as to be killed by the fungus. The presence of these plants in a field enables the fungus to live from year to year in the absence of its grain hosts. Consequently, a short rotation may not be effective in eradicating the fungus.

There seems to exist a direct correlation between such climatic factors as moisture and temperature and the amount and severity of take-all. Early wet springs favor the disease and cause average losses of from 2 to 3 per cent, while late dry springs and, to a less extent, late wet springs retard the disease and result in losses ranging from those that are negligible to those less than 1 per cent.

The disease is much more destructive to early planted than to late-planted winter wheat. This is due to the fungus being more virulent during the warm weather of early fall than it is during the cooler weather later on.

Usually little loss from this disease is experienced on an acid soil, since the fungus grows best in an alkaline medium. On heavily limed land the disease is more severe.

Control

It is very difficult to control this disease completely, but the damage caused by it can be held to a minimum by the practice of certain control measures.

A four- or five-years rotation, which includes clean culture crops, like potatoes or corn, should be practiced. In practicing clean culture, one should take into consideration that the fungus lives for several months in the soil, for almost a year on the old stubble, and for two or three years on wild grasses. On farms where such a rotation had been practiced, there was on the average less than 1 per cent of loss, but where wheat had followed wheat, the loss amounted to 5, 10, or even 20 per cent in some cases.

As this fungus is largely carried from field to field and from farm to farm in straw from infested fields, such straw should, so far as possible, be kept away from wheat and rye fields. Since bits of straw containing the perithecia may be carried with the seed, all wheat should be thoroly cleaned before planting.

Only resistant varieties of wheat should be planted in fields or localities where take-all is severe. Foward, Dawson, and Honor are fairly resistant, while Junior No. 6, Leap, Turkey, and Durum types are very susceptible to this disease. Considerable loss from the disease will be avoided if winter wheat is planted late.

The application of lime to fields should be avoided if this disease is a factor of sufficient importance to warrant the discontinuance of such a practice.

HELMINTHOSPORIUM DISEASE OF WHEAT

(Caused by *Helminthosporium sativum*)

Helminthosporium disease is fairly common in New York, probably occurring in a large percentage of the fields of both winter and spring wheat. The loss caused by it is usually less than 1 per cent, but in years when weather conditions favor it, the loss may be larger.

The disease, in addition to affecting wheat, commonly affects rye, oats, barley, and certain wild grasses, being specially common on quack grass.

Symptoms

All parts of the wheat plant may become affected.

On seedlings and young plants.— Many infected seeds fail to germinate, while others are so weakened that either the shoots fail to reach the surface of the ground or, if they do emerge, they are very weak, spindling, or stunted. The roots of many of these weak plants exhibit numerous brown lesions and are in many instances so badly rotted that the plants die before the heads are produced. Chocolate-brown lesions varying in length from one-fourth to more than one inch, may occur during the early spring on the basal leaf and its sheath. Infected plants not killed in the seedling stage sometimes recover and grow to maturity.

FIGURE 14. TYPICAL DISCOLORATIONS ON THE BASE OF WHEAT STEMS CAUSED BY HELMINTHOSPORIUM

Photographed by H. H. McKinney, Office of Cereal Investigations, United States Department of Agriculture

On the stems and heads.— On older plants the symptoms of this disease are like those of take-all in the following respects: The plants soon after reaching the jointing stage show distinct dwarfing, turn yellow, and die. Definite diseased areas may appear in the fields in addition to the presence of many single-dwarfed plants intermixed

with healthy ones. The roots are brittle and decayed and the plant easily parts from the roots at the crown. The heads are poorly filled and shriveled, the lower base of the stem shows a dark discoloration (figure 14), and on the lower internodes there are definite chocolate-brown discolorations.

This disease differs from take-all in that there is no thin black gelatine-like plate between the lower part of the stem and the inner leaf sheath, nor are there any spore cases formed on the base of the stem. Furthermore, plants affected with Helminthosporium disease have lesions which appear on leaves, glumes, and kernels. These lesions are elongated, rather irregular in outline, with a light margin and a dark-brown, or creosote-colored, center (figure 15). The upper nodes of the infected plants often have a dark velvety appearance due to the formation of spores at this point. Finally, the seeds which are never discolored in the case of take-all are conspicuously of a dark-brown to nearly black color, involving more or less extensive areas on the germ end of the kernel and occasionally extending for some distance along the furrow.

FIGURE 15. LESIONS ON WHEAT LEAVES CAUSED BY HELMINTHOSPORIUM

Photographed by H. H. McKinney, Office of Cereal Investigations, United States Department of Agriculture

Cause

This disease is caused by a fungous parasite which passes the winter as mycelium within affected seed. It also may live for several years in old dead stubble and roots of wheat and other susceptible plants, or for six to twelve months in the soil.

When infected seed is sown, the fungous mycelium renews its growth and extends into the roots as the seed sprouts. The mycelium in old debris or in the soil may attack the roots from healthy seed. In either case the fungus is able to grow from one root to another, eventually causing their death and decay.

During the following spring, new or secondary infections result from spores that are borne either on lesions on the stem and leaf sheaths of the growing plants or from spores produced on nodes of one-year-old dead stems of host plants. These spores are distributed by such agents as

rain, water, and particularly wind. Once the fungus has sporulated on the plants, repeated inoculations and infections may occur as in the cereal rusts.

The production and the dissemination of millions of spores on affected wild grasses growing in or near cereal fields apparently greatly increase the secondary infections of cereals.

Control

Clean seed is essential, since the disease is seed borne. Such seed should be obtained from fields free from the disease, by careful grading which removes many of the diseased seed, or by treating the wheat with hot water as recommended for the control of loose smut of wheat (page 12).

This disease is always more severe where fields have been cropped continuously to wheat than where a rotation has been practiced. Therefore, the loss may be lessened by practicing a four- or five-years rotation.

Since this fungus does not thrive at soil temperatures of 60°F. or below, wheat should be sown as late in the fall or as early in the spring as other conditions will permit. As several wild grasses, including quack, harbor the pathogene, the eradication of such grasses from fields and fence rows around cereal fields is a precautionary measure worth practicing.

ANTHRACNOSE OF WHEAT

(Caused by *Colletotrichum graminicolum*)

Anthracnose is present nearly every year in most of the wheat fields in New York. The average annual loss due to this disease apparently varies between 0.5 and 1 per cent. On low, damp, poorly drained soil where the disease is most severe losses as high as 15 per cent have been observed.

Wheat is not so susceptible to this disease as rye but is more resistant than oats, barley, and corn. In addition to the cereals, about twenty species of grasses are reported as being susceptible. These include such common grasses as timothy, blue, quack, red top, and orchard.

Symptoms

The disease occurs on all parts of the host plants. The first symptom on wheat appears just after the grains start to fill. This consists of a premature ripening accompanied by more or less general whitening and blighting of the wheat heads, resulting, in severe cases, in a decided shriveling of the grain. A brownish to purplish water-soaked discoloration occurs on the stems near the nodes. This discoloration is most pronounced on rye.

The characteristic sign of the disease is a large number of small black elevations (figure 16) the size of pin points. These are most numerous near the nodes of the stem and on the dead leaf sheaths and leaves.

Cause

This disease is caused by a fungus which probably passes the winter as spores on the seed coat and as mycelium inside of the shriveled seed. It also passes the winter on stubble, straw, and other plant debris. Details of infection are imperfectly known but it is assumed that air and water-borne spores, upon germination, may penetrate any part of the host plant.

Control

Methods which will completely control anthracnose are unknown. Since the pathogene passes the winter in plant debris of the cereal crops and grasses, rotation and cultivation should be practiced. The pathogene also survives in manure produced from infected straw. Hence wheat fields should not be top-dressed with infested manure.

Infected seeds may be largely eliminated by a rigorous screening and by the use of only the larger seed for sowing. The spores which adhere to the outside of the seed may be killed by treating the seed with formaldehyde, before planting, in the same way as that recommended for the control of stinking smut of wheat (page 10). The use of well-drained land will aid in preventing heavy infection.

FIGURE 16. WHEAT ANTHRACNOSE

GLUME BLOTCH OF WHEAT

(Caused by *Septoria nodorum*)

Altho glume blotch of wheat is usually present in New York, the resulting decreased yield in years of normal weather is probably less than 0.5 per cent. The loss may be considerably higher in years when the rainfall between the flowering time and the harvest of the grain is excessive.

The decrease in yields results from the death of tillers of severely affected plants and from head infections that reduce the size of the head and cause a shrinking of the kernels. In extreme cases head infection may reduce the yields of individual plants as much as 50 per cent.

Under New York conditions, Velvet Chaff is more susceptible than any other commonly grown variety of wheat.

Symptoms

This disease occurs most commonly on the glumes, but it may also be found on the leaves and the stems.

On the glumes.— Shortly after blossoming time, or between two and three weeks after the emergence of the head from the leaf sheath, small, irregular, slightly darkened brownish spots appear on the upper half of the outer glumes of one or more spikelets on a head (figure 17). These spots enlarge and become chocolate-brown in color. In severe cases all of the glumes become infected, and all of the exposed parts become discolored. Small fruiting bodies, the pycnidia, resembling tiny black dots, soon appear on the glumes.

FIGURE 17. GLUME BLOTCH OF WHEAT

On the leaves.— Leaf spots may appear on the leaves at any time from two weeks after the young plants emerge from the ground until they reach maturity. The central areas of these spots become dry and lighter, sometimes almost white in color. The margin of living tissue is often indicated by a brownish zone. Pycnidia appear in these spots on both surfaces of the leaves. The entire leaf is sometimes killed as a result of the coalescence of two or more spots.

On the stems.— The nodes become dark brown in color and the internodes light brown. Pycnidia are found only at the nodes.

Cause

Glume blotch of wheat is caused by the fungus *Septoria nodorum*. Thousands of spores are contained in the fruiting bodies that are found in the

lesions on leaves, nodes, and glumes. Since straw and chaff are scattered about at threshing time, the means of dissemination of the fungus is obvious. Infested straw transported for feed and commercial purposes carries the fungus over greater distances. Likewise, chaff bearing pycnidia may be included along with improperly cleaned grain. The infection of fall-planted wheat may result from spores from fruiting bodies on parts of diseased plants. The fungus passes the winter in the leaves of infested winter wheat as well as in old plant parts, viable spores being present in the pycnidia in the spring. These spores serve as the inoculum for spring infections which take place at about the time the tillers show further and rapid development. Subsequent crops of spores, produced in interlapped cycles of from twelve to sixteen days, supply an abundance of inocula for infection of leaves and heads thruout the season.

Another kind of spore, produced in structures called *perithecia*, has been found on the old wheat stems, and it is likely that these spores, when present, may pass the winter and cause infections in the spring.

Control

Since the fungus is disseminated with straw and chaff, an effort should be made to keep these away from land to be planted to wheat. This can be accomplished by cleaning the wheat to remove all chaff. Crop rotation should be practiced as well as the avoidance of top-dressing wheat fields with manure containing straw of the previous crop.

Since the fungus is known to infect them, volunteer rye and blue grass (*Poa pratensis*) should be eradicated by cultivation from fields where a wheat crop is planted.

SPECKLED LEAF BLOTCH OF WHEAT

(Caused by *Septoria tritici*)

The speckled leaf blotch is present in nearly every wheat field in New York. The loss from this disease, however, is probably never more than a small fraction of 1 per cent. During late fall and early spring, the tillers and, in extreme cases, a few individual plants may be killed. Rye and blue-grass, in addition to wheat, may be attacked.

Symptoms

The blotches, or spots, caused by this disease are found only on the leaves and leaf sheaths. These spots are circular to irregularly oval during the fall and are scattered over the blades of the leaves. The center of the spot is usually somewhat light colored but still greenish shading off into the natural color of the leaf. The spot is thickly beset

with small, black, bead-like fruiting bodies (pycnidia) which give it its speckled appearance. In the spring the spots become longer and reddish brown in color. The centers of the older spots become a lighter brown. These spots on increasing in size and coalescing may involve the whole leaf and bring about its death.

Cause

Speckled leaf blotch is caused by the fungus *Septoria tritici*. Portions of the leaves containing the fruiting bodies of the fungus are widely scattered by the wind or other agencies at harvesting and threshing time. The spores contained in the fruiting bodies may remain alive until the next spring. However, many of them escape during the summer and fall and, on coming in contact with wheat leaves, cause infection. Such infection of volunteer wheat during the late summer greatly increases the number of spores which may infect the fall-planted crop. It is not uncommon to find the disease on winter wheat almost as soon as it comes up. After it is once infected, new cycles of spore production and infection are repeated, with the exception of two or three of the coldest months, thruout the year.

Control

Since the fungus is disseminated with the leaves, every effort should be made to keep the diseased leaves of the preceding crop away from land to be planted to wheat. This can be accomplished by cleaning the wheat in order to remove all bits of leaf tissue. Crop rotation should be practiced and fields of growing wheat should not be top-dressed with manure containing straw of the previous crop. Volunteer rye and blue grass should be eradicated from the field by cultivation before the wheat crop is planted.

POWDERY MILDEW OF WHEAT

(Caused by *Erysiphe graminis*)

Powdery mildew is present in practically every wheat field in New York. From a trace to 100 per cent of the plants in individual fields may be affected, the average over a period of years being from 7 to 25 per cent. The loss in yield caused by this disease in the entire State is estimated to vary from 0.5 to 1 per cent, but on several occasions a loss in individual fields of at least 10 per cent has been observed.

Symptoms

This disease may occur on all parts of the plant above ground, but it is most serious on the leaves and the heads.

On the leaves.— The first evidences of the disease are small areas of dull grayish, superficial, cobwebby growths which appear soon after the

plants push thru the soil (figure 18). As the growth of the plants continues, the superficial powdery layer becomes denser and increases in size until it may cover large areas of the leaf. As the plants reach maturity, small spherical black bodies develop within these cobwebby growths. In severe cases the leaves may become crinkled, brittle, and often spirally twisted or deformed. The leaf tissue under the mass of the powdery growth is livid yellow in color which grades into a brick red in the oldest diseased regions.

On the heads.— The effect on the floral structures depends on the time and the severity of the disease. If the heads themselves are affected, death may result. If the leaves of the young plant are seriously injured, the floral structures may fail to develop or may be withered.

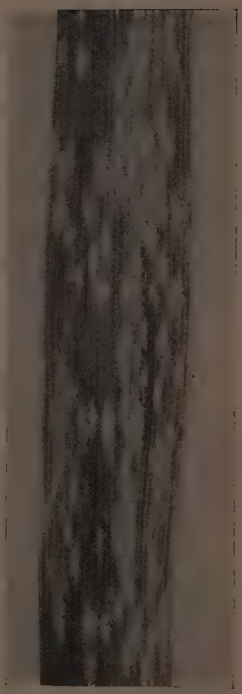

FIGURE 18. POWDERY MILDEW ON A WHEAT LEAF

Photographed by E. B. Mains, Indiana Agricultural Experiment Station

Cause

The fungus *Erysiphe graminis* which causes powdery mildew exists in specialized forms, each restricted to a certain cereal. Forms are found on wheat, barley, rye, and oats, and under no conditions will the fungus from one grain attack another. The mildews on grasses in New York are not known to affect the cereals.

Altho the major part of the fungus is on the surface of the leaf, giving the affected areas their characteristic mildewed appearance, small suckers, called *haustoria*, are sent into the epidermal cells. Multitudes of spores (conidia) are produced by the mycelium on the surfaces of the plants. These are blown or washed to healthy plants where they germinate in the presence of moist air and cause infection. By means of successive cycles of conidial production, dissemination, and infection, the fungus is able to spread rapidly during the spring and the summer. The black spherical bodies found in the powdery masses are the winter spore cases (perithecia) that pass thru a rest period until the next spring, when another form of spores (ascospores) is produced. In the presence of moisture and proper temperature, the perithecial spore cases burst and liberate the ascospores which infect the host in the same manner as do the conidia. The disease has been found to be most severe when the weather is moist and warm during the two months preceding harvest.

Control

No practical treatment for the control of this disease has been found. The avoidance of thick stands and the practice of crop rotation will help somewhat to keep the disease in check. Sulfur dusting controls mildew, but this may not be practicable under field conditions for the control of this disease alone.

Certain varieties of wheat, not adapted to New York conditions, have been found to be resistant to powdery mildew, and in time satisfactory varieties resistant to the disease may be developed.

BASAL GLUME ROT OF WHEAT

(Caused by *Bacterium atrofaciens*)

Basal glume rot probably is present every year in many of the wheat fields of New York. It is of moderate importance only, for it has never been observed to cause a loss of more than 10 per cent in any field and usually the loss is very much less. So far as is known, wheat is the only susceptible plant.

Symptoms

The leaf, head, and seed are affected (figure 19).

On the leaves.— The first evidence of the disease is the appearance of small, dark, water-soaked spots. Their color soon changes to yellow, and they enlarge and elongate slightly. The spots finally become light brown and consist of dry dead tissue.

On the head.— The most characteristic feature of the disease is the dull brownish black area at the base of the affected glumes (figure 19). This discoloration is more pronounced on the inside of such glumes. It usually is confined to the lower third of the glumes but sometimes extends over nearly the whole surface. Often the only outward sign of the disease is a narrow dark line at the junction of the rachis and spikelet.

The seed enclosed by diseased glumes shows varying degrees of shriveling. The base, or germ end, of the diseased kernels varies in color from a scarcely noticeable brown to a charcoal black and in severe cases may even appear as if charred.

Cause

Basal glume rot is caused by a bacterial organism (*Bacterium atrofaciens*). These bacteria are known to live for at least seventeen months within the diseased seed. The means by which the bacteria get from the seed to the new plants have not been determined. It is known that they are able to enter healthy plants thru the stomates. Therefore, they probably spread from plant to plant by rain or wind.

Control

Little is known concerning the control of this disease. The use of seed which is free from germ-end discoloration and the practice of fanning to remove shriveled seed are control measures which should be practiced.

FIGURE 19. BASAL GLUME ROT ON WHEAT HEAD, KERNELS, AND GLUMES

Photographed by the Laboratory of Plant Pathology, United States Department of Agriculture

ERGOT OF WHEAT

(Caused by *Claviceps purpurea*)

Both the spring and the soft winter wheats grown in New York apparently are fairly resistant to ergot (figure 20). Never more than a few heads have been found during any year. It, therefore, seems to be of little economic importance.

FIGURE 20. ERGOT ON WHEAT
Germinating sclerotium, lower left

The symptoms, cause, and control of this disease on rye are discussed on pages 69 to 71.

WHEAT STRIPE

(Cause unknown)

Wheat stripe is confined almost entirely to wheat fields in New York. Here it occurs in many fields, being especially common in the western part of the State but apparently causing very little damage. The trouble is much more prevalent on Junior No. 6 (Gold Coin) than on other varieties. The disease has also been observed on the following varieties: Red Rock, Dawson, Honor, and Pennsylvania 44.

Symptoms

The leaves are the only part of the plant directly affected. The disease is observed first after the plants start to head, when long, light-yellow to brownish streaks may extend the entire length of a leaf. These streaks vary in width from one-eighth to one-fourth inch.

Cause and control

Practically nothing is known concerning the cause and the control of this disease, but it is thought that it may be eliminated by the use of seed from healthy plants.

NEMATODE DISEASE OF WHEAT

(Caused by *Tylenchus tritici*)

Altho the destructive Nematode disease is said in one report to have been found in threshed wheat from New York, no certainty exists that the grain in question may not have been grown elsewhere. The disease is now known to occur in seven south-central Atlantic Coast States and in two States on the Pacific Coast.

In addition to wheat, rye is affected with almost equal severity, but oats, barley, and grasses are practically immune.

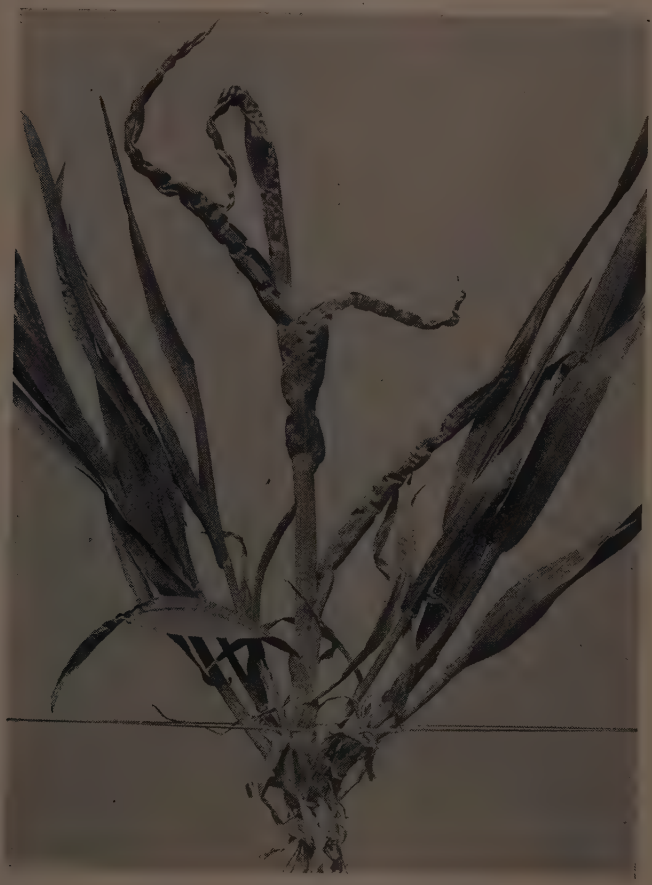

Figure 21. Nematode disease of wheat

Symptoms

In the seedling stage the disease causes wrinkling, twisting, or various other distortions of the leaves (figure 21). Usually the emerging leaf is held by the older one, thus causing a "buckling" of the younger leaf while still in the enclosing sheath. These distortions of the seedlings may result in their death. Infected plants are thicker and shorter than normal ones. The heads ordinarily are smaller, stay green longer, and have distended glumes as in bunt-infected heads. The normal wheat kernels are replaced by hard galls which are darker, shorter, and thicker than the healthy kernels.

Cause

Each of these wheat galls contains thousands of minute living eelworms, or nematodes. In the autumn these young eelworms escape into the soil from the galls which either fall from the old plants or are planted with the seed. The eelworms move from the soil onto the young seedlings where they locate between the leaf sheaths near the bud and are carried up by the growth of the plant. On the head of the plant they enter the flowers and later convert each grain into a gall. Within these galls they reach maturity and give rise by means of eggs to a new generation. By harvest time the galls are dry and in these the eelworms can remain alive for several years.

Control

Climatic conditions in New York are unfavorable to the eelworms, and it is therefore unlikely that this disease will ever become serious in this State. Care should be taken, however, to make certain that any seed brought into the State from an infested area is free from galls. If the disease is found to be present, it can be controlled by practicing a three- to five-years rotation and by the removal of all galled kernels from all wheat or rye seed before planting. The galls may be removed by skimming, since they will float on a 15- to 20-per-cent brine solution, while the healthy seed will sink.

OATS

LOOSE SMUT OF OATS

(Caused by *Ustilago avenae*)

Loose smut is the most destructive disease of the oat crop in this State. It occurs only on oats and is present in nearly every field planted with untreated seed. The average reduction in yield for the State chargeable to this disease is about 3 per cent. Usually the loss to the individual grower is determined by the number of years the crop in question is removed from the use of treated seed. Fields grown from treated seed

seldom have more than a few smutted heads; those grown from seed one crop removed from treatment have an average of about 2 per cent smut; while fields grown from seed several generations removed from treated lots have an average of about 8 per cent of smut, altho under these conditions, a crop of oats in which 46 per cent of the heads were smutted has been observed by the writer.

Symptoms

The disease is first evident as the heads emerge. The spikelets are usually completely destroyed, even the awns and the glumes being replaced

FIGURE 22. HEALTHY AND SMUTTED PANICLES OF OATS
Left, healthy oat head; center two, covered smut; right two, loose smut

by the dusty olive-brown spore masses. The diseased heads fail to form a spreading panicle like the healthy ones; that is, the branches of the head, on account of their lighter weight, stand erect (figure 22). Immediately after a smutted head emerges, the delicate membrane surrounding the smutty mass of spores ruptures and the spores are blown or washed away, eventually leaving only the flower stalk. The smutted plants are, on the average, slightly shorter than the healthy ones. Commonly all of the heads in a plant are diseased, altho occasionally some of them are healthy; furthermore, all of the spikelets in a head are usually smutted, but sometimes the uppermost spikelets escape the disease and mature normal seed.

It is often very difficult to distinguish between the loose smut of oats and another one known as *covered smut*. The following list of symptoms of the two diseases may help one to distinguish them:

Loose smut	Covered smut
1. Spore mass Olive-brown in color.	1. Spore mass Black-brown in color.
2. Glumes Inner glumes usually entirely destroyed; outer glumes either completely destroyed or, when partially so, ruptured at the base exposing the spore mass.	2. Glumes Inner glumes not fully destroyed; outer glumes nearly intact and enclosing the spore mass.
3. Membrane Gray, delicate, rupturing and releasing spores shortly after head emerges; at harvest only flower stem remains.	3. Membrane Usually persistent, gray, remaining intact until harvest.

Cause

The olive-brown masses of the loose smut are composed of millions of thick-walled spores of the causal fungus. As the healthy heads emerge a little earlier than the smutted ones, they have reached the blossoming state of development by the time the smut spores are being disseminated. These spores are carried to healthy heads by the wind or by healthy and smutted heads coming in contact with each other. They either lodge on the outside of the glumes, or, falling between the open glumes, adhere to the stigma and around the ovary. Those spores lodging on the outside of the hull do not play an important rôle in the infection of the seed. In the case of hulless-oat varieties they fall directly on the young ovary and

are in these cases very important in subsequent infection. Those that adhere to the stigma and other parts of the flower germinate by the production of a short delicate sprout upon which may be borne a number of thin-walled spores (sporidia). These germinate promptly by the formation of a germ tube. The germ tubes from the chlamydospores or those from the sporidia invade the seed coat of the young ovary or any of the other organs of the flower. Here they form an extensive mycelium as the kernel matures, and this finally becomes dormant along with the seed. Under exceptionally dry conditions at the time of inoculation the chlamydospores may not germinate and infect the seed coat until after the oats is stored.

Thus the fungus passes the winter inside the hull of the seed as resting mycelium chiefly in the seed coat and in the inside of the hull. It is known that the mycelium in the seed coat of the grain is chiefly responsible for the smutted plants arising from inoculated seed. In the case of hulless oats, the fungus passes the winter as mycelium only in the seed coat. In the spring when the seeds are planted and sprout, the growth of the mycelium is renewed. Penetration of the young sprout of the oat plant takes place before the plant reaches the surface of the soil No infection results after this time. Once inside the plant the fungus continues its growth in the young developing tissues without any marked external evidence of the disease. As the young floral parts are formed, the fungus develops vigorously within them, bringing about their replacement with its own fruiting bodies. It is not until these affected organs emerge that the percentage of diseased plants in a field can be readily determined.

Soil temperature and soil moisture at planting time apparently have a marked influence on infection. High soil moisture combined with high soil temperature results in complete elimination of smutting, while low soil moisture with medium temperature is accompanied by relatively high percentages of smutted plants. However, low, poorly drained areas in fields may have two or three times as much smut as the higher and drier parts of the field. Low soil temperatures usually result in a reduction in the amount of smut but this is not so marked as in the case of high temperatures.

Control

Sowing oats fairly early in the spring in a well-drained and a well-prepared seedbed will aid in reducing the amount of smut. Seed treatment, however, should always be practiced if the seed comes from a field showing any smut.

A treatment that will control this smut effectively involves the use either of a material that will kill all of the fungous mycelium in the seed coat of the oat kernel and the hull at the time of treatment or one that

will remain on the seed and kill the growing mycelium before it invades the germinating seed. Formaldehyde and copper carbonate, respectively, act in the two manners indicated. Formaldehyde, when carelessly applied, reduces the viability of the seed. For hulled oats the dry-formaldehyde treatment is the most economical and efficient.

Copper carbonate is used in the form of a dust. The material clings to the seed which is sown, later going into solution sufficiently to prevent infection. For hulless oats copper carbonate is the best treatment. For hulled oats it is only about 90 per cent as efficient in control as is formaldehyde.

Dry-formaldehyde treatment

Directions

1. Pile the oat seed, after cleaning with a fanning mill, on a clean barn floor or canvas or in a tight wagon box.

2. Dilute one pint of 40-per-cent formaldehyde solution (formalin) with one pint of water and pour it into a quart hand sprayer of the type commonly used about stables. This amount (one quart)will treat fifty bushels of seed. If a smaller quantity is to be treated, the amount of formaldehyde should be lessened proportionately.

3. While the oats are being shoveled from one pile to another, spray a little of the solution over each shovelful. Two strokes of the handle give about the right amount.

4. After all the oats are treated in this way, shovel them into a pile and cover them with blankets or canvas or with grain sacks which have been sprayed inside and out with the solution.

5. Allow the seed to remain covered for at least five hours, after which they may be bagged and drilled.

6. Treatment may be made any time previous to sowing.

Precautions

Formaldehyde vapor irritates the mucous membrane of the eyes, the nose, and the throat, therefore:

(1) Hold the sprayer close to the oats.

(2) Work from one side of the pile.

(3) Have a circulation of air in the room where the treatment is made.

Advantages

(1) The treatment does not wet the seed, thus making it possible to treat and drill on the same day.

(2) The treatment may be made several weeks ahead of planting.

(3) It is easy to use and is effective, giving complete control.

(4) The seed is not injured when care is taken in making the treatment, and does not stick to the drill.

Copper-carbonate-dust treatment

Directions

The dust is applied in the same manner as that described for the control of stinking smut of wheat (pages 6 to 7) with the exception that four ounces of dust should be mixed thoroly with each bushel of oats. This treatment is very effective in the control of smut of hulless oats.

COVERED SMUT OF OATS

(Caused by *Ustilago levis*)

The covered smut of oats is not usually so common as the loose smut. It occurs in about 66 per cent of the oat fields in this State and causes an average loss of about 1 per cent. Oats is the only crop affected by this disease.

Symptoms

The symptoms of this disease are similar to those of the loose smut of oats (pages 42 to 43). In the covered smut the affected heads appear to be almost normal when they first emerge and have a somewhat more spreading and drooping panicle than those heads affected with loose smut (figure 22). The covered smut replaces the kernel but the outer glumes remain intact. The gray membrane enclosing the black spore mass seldom ruptures until harvest or threshing time.

Cause

The black spore masses consist of millions of spores which are disseminated to healthy seed during harvest. The spores of this fungus are largely disseminated at harvest time, altho some are scattered by wind to the late-blooming oat flowers. These germinate at once and infect the blossom just as in loose smut. At threshing time large numbers of spores are dusted over the grain. Some find their way inside the hulls or, in the case of hulless oat, fall directly on the naked seed. These spores germinate during storage and infect the seed coat of the grain. When the oats are sown, the same conditions of warmth and moisture which cause the seed to sprout also cause the mycelium in the seed coat to become active. The mycelium now sends out new branches which invade the oat seedling before it reaches the surface of the ground. The fungous mycelium on entering the oat plant keeps pace with the growing tip of the plant, finally entering the young developing kernels. A new crop of spores is finally formed from the mycelium which invades the developing flowers.

Control

The control of covered smut is the same as that for loose smut (pages 43 to 45).

STEM RUST OF OATS

(Caused by *Puccinia graminis avenae*)

Stem rust is seldom severe on oats in New York. While it occurs in over one-half of the fields, it usually appears too late to cause any appreciable damage. Orchard and meadow fescue grass are also subject to this disease.

Symptoms and cause

For the symptoms and cause of this disease refer to the discussion of stem rust on wheat (pages 14 to 18).

The fungus causing this disease is often harbored by the common barberry, but up to the present time, few cases have been found in this State in which the barberry seemed to play an important rôle in the life history of the organism.

Control

The removal of all common barberry bushes for a distance of two miles from an oat field will greatly reduce the amount of rust. Richland and White Russian are two varieties of oats which are resistant to this rust and can be planted in any area where the rust is severe and where it is impossible to destroy the barberry. If oats are sowed in the early spring, the crop will usually reach maturity before the rust can cause much damage.

CROWN RUST OF OATS

(Caused by *Puccinia coronata*)

In New York, crown rust is the most destructive leaf rust of cereals. It causes a loss to the oat crop which is exceeded only by the smut diseases. This rust is present in practically every oat field and causes an average yearly loss of from about 2 to 3 per cent.

In addition to oats, this disease also occurs to some extent on several grasses, for example, sweet-scented vernal and tall oat grasses. The crown rust which is so common on meadow fescue does not affect oats.

The varieties Victory, Silvermine, and Swedish Select are susceptible to crown rust, while White Russian and Richland have generally been reported as resistant. In a test under observation for two years, White Russian exhibited very little more resistance than the susceptible varieties. The early maturing Richland oat is very resistant to this rust.

Symptoms

This rust is confined largely to the leaves, but it may also occur on the stem and the head of the oat plant.

The first evidence of the disease appears on the leaves soon after the plants start to head, about June 20 to 30. This consists of pustules

irregularly scattered over both leaf surfaces (figure 23) and to a smaller degree on the stems. The individual pustules are small, oval, brownish or reddish yellow in color, and surrounded by the broken epidermis. Leaves are so severely affected at times as to give the whole field a decided reddish tinge.

As the plants mature, the red stage is replaced by the black stage characterized by pustules (telia) which appear as grayish black spots. These are covered by the epidermis for a long time and are usually arranged in a zone surrounding the pustules of the red-rust stage.

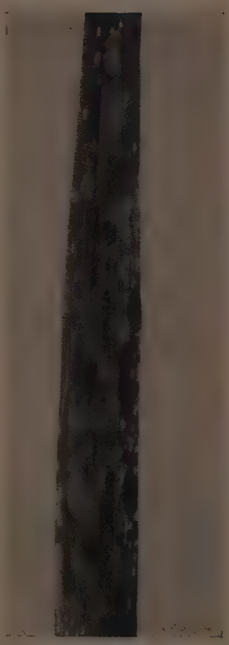

FIGURE 23. CROWN RUST ON OAT LEAF

Cause

The fungus causing crown rust of oats passes the winter under New York conditions as black-rust spores (teliospores), the red-rust spores, or urediniospores, being unable to survive the winter temperatures of this latitude.

In the early spring the teliospores germinate by forming small secondary spores (basidiospores) which can infect only the buckthorn (Rhamnus sp.). The infection of the buckthorn results in the production during early May of small yellowish swellings on the lower surface of the leaves. In these swellings are formed a number of small cups which are filled with yellow spores (aeciospores). These yellow spores can in turn infect only oats and a few grasses. Under field conditions these spores are usually blown from the buckthorn directly to the oats where, under favorable weather conditions consisting of a temperature of about 65°F. and moisture to provide a film of water over the leaves, they germinate and infect the oats. This infection results in the formation of the red-rust stage. The red-rust spores are wind-borne and, under weather conditions similar to those just mentioned, can infect oats directly, producing the red-rust stage. Such infections may be repeated again and again as long as the oat remains in a susceptible stage of development. As the plants reach maturity, the red-rust stage is followed by the black, or telial, stage.

The fungus passes the winter in the red-rust stage in the southern part of the United States and produces heavy epidemics there early in the spring. It may reach New York by means of wind-blown spores.

Control

Comparatively speaking, early maturing oats largely escape the crown rust. The use of early maturing varieties and early sowing will aid in avoiding this disease.

Since the buckthorn harbors the fungus, this shrub should be removed from the fence rows in the vicinity of oat fields or, better still, be eradicated from the neighborhood.

If the crown rust in any locality is so severe on the commonly grown varieties as to cause material reduction in yield, a resistant variety like Richland may be tried.

SCAB, OR FUSARIUM BLIGHT, OF OATS

(Caused by *Gibberella saubinetii*)

Seedling blight, or scab, of oats occurs very rarely in New York and is of little or no economic importance.

For further details concerning the disease, refer to the discussion of wheat scab (pages 21 to 24).

FIGURE 24. HALO BLIGHT ON OAT LEAVES

Photographed by the Office of Cereal Investigations, United States Department of Agriculture

HALO BLIGHT OF OATS

(Caused by *Bacterium coronafaciens*)

The halo blight of oats is a bacterial disease which occurs, to some extent at least, in this State every year but becomes of economic importance only during certain seasons when weather conditions are particularly favorable for its development. This disease rarely, if ever, affects other cereals in the field.

Symptoms

Halo blight is most conspicuous on the leaves but it may also occur on the leaf sheaths and glumes.

On leaves and leaf sheaths.— Lesions may appear on the first seedling leaves and on all subsequent leaves. These lesions are oval, and consist of a yellowish area surrounding a center of sunken dead tissue. The yellowish green halo-like margin is very characteristic (figure 24). Sometimes this halo extends as a streak thruout the entire length of the leaf. The spots in many instances coalesce, killing the

leaves. The dead tissues may become pinkish or reddish brown in color, but even after the leaf is dead the halos are usually still distinguishable.

On the heads.— A single lesion on a glume is characterized by a typically light-green to yellow-colored halo about the point of infection. When the whole glume is infected, the tissue becomes yellow and translucent between the veins.

Cause

The life history of the bacteria which cause this disease has not been fully determined. It is, however, thought that the bacteria live over from crop to crop on the seed, in the soil, and on dead plant parts. When the oats are planted, the bacteria from the several sources are likely to be carried to the young leaves of seedlings by wind-blown rain. In the same way, the bacteria are probably carried to the older plant parts from the lesions formed on the young leaves. The bacteria causing this disease have been observed to infect the oat plant thru wounds more easily than thru uninjured surfaces.

Humid, cloudy weather is especially favorable for the development of the disease.

Control

To eliminate the chance of infection from the soil or dead plant parts, a three- to five-years rotation should be followed.

POWDERY MILDEW OF OATS

(Caused by *Erysiphe graminis*)

Powdery mildew is of little economic importance in New York. It has been found on oats very late in the season, but only in small amounts.

For the symptoms, cause, and control of this disease, refer to the discussion of powdery mildew on wheat (pages 34 to 36).

STERILITY, OR BLAST, OF OATS

(Cause unknown)

Blasted oat heads are usually present in most of the oat fields in this State. On the average about 1 per cent of the spikelets are blasted, but in individual cases the percentage may be much higher.

Symptoms

Sterility is confined to the flowers. From one single flower to nearly one-half of the flowers of a panicle may be blasted. These affected flowers have pale-yellow or colorless paper-like glumes which fail to set seed. The glumes may vary in size from minute rudiments to full-sized empty glumes.

Cause

The cause of sterility is not known with certainty. However, weather conditions, such as temperature at heading time, are considered to be important factors. In addition, inherited characters resulting from crossing different varieties of oats may also play an important rôle in determining the amount of blast.

Control

On account of the nature of sterility there is apparently no practical control.

ANTHRACNOSE OF OATS

(Caused by *Colletotrichum graminicolum*)

This disease of oats is rarely observed in New York and is considered to be of little importance.

A more detailed discussion of this disease is given for anthracnose of wheat (pages 30 to 31).

ERGOT OF OATS

(Caused by *Claviceps purpurea*)

Oats are more resistant to ergot than any of the other small grains. While an occasional head of ergot may appear in oats, the disease is never likely to be of any economic importance.

The symptoms, cause, and control of this disease are discussed for ergot of rye (pages 69 to 71).

BARLEY

LOOSE SMUT OF BARLEY

(Caused by *Ustilago nuda*)

Of the various diseases attacking barley in this State, loose smut is the most destructive. It occurs in practically every barley field and is increasing in importance. On the average it causes a loss of about 2 per cent, altho it is not uncommon to find fields having 10 per cent of smutted heads.

Barley is the only crop affected by this smut, and of the various varieties of barley, Alpha, a two-rowed barley, is probably the most susceptible.

Symptoms

Loose smut becomes evident as soon as the barley head emerges from the leaf sheath. An affected head appears as an olive-brown powdery mass of spores which has replaced all parts of the spikelets, sometimes even including the awns. This mass of spores is held by a thin silvery membrane which usually does not rupture until blossoming time. By harvest

time most of the spores in an affected head are usually blown away, leaving only the bare stalks which are easily overlooked. (Figure 25.)

All the heads of a diseased plant may be destroyed, but it is not unusual to find affected plants of which certain of the heads have escaped infection. A few of the smutted heads are produced on tall stalks that stand above most of the healthy ones.

There are two common smuts of barley which are often confused. The following characters will help to differentiate them:

Loose smut	Covered smut
1. Smutted heads come out early and can be seen as soon as the heads emerge from the leaf sheath.	1. Smutted heads come out about ten days later than heads affected with loose smut and after healthy heads emerge.
2. Smutted heads usually stand higher than the average healthy heads and are free from the leaf sheath.	2. Smutted heads stand lower than the average healthy heads and are more or less enclosed in the leaf sheath.
3. Smut masses are liberated soon after emerging, and smut is carried away by the wind, leaving bare stalks before harvest time.	3. The smut mass usually persists on the stalk until harvest.
4. The smut mass is olive-brown in color, and is enclosed in a silvery membrane which ruptures early.	4. The smut mass is coal-black to purplish-black in color. The gray membrane persists until harvest.

Cause

Loose smut of barley is caused by the fungus *Ustilago nuda*. The pathogene differs from the other smut fungi in that it either has a life history of a dual nature or is composed of races which differ in their habits. The essential difference in the two types of development is in the manner in which the fungus passes from one crop of barley to another.

In the first type of development, the olive-brown masses of spores on the affected heads are disseminated by the wind about the time the barley comes into blossom. Some of these spores fall on the healthy heads and may reach the pistils of the flowers where they germinate at once and produce a delicate fungous thread which grows into the embryo of the young kernel. This is known as flower infection. Here the fungus soon ceases growth and may live in the ripened seed in a dormant condition for several

FIGURE 25. LOOSE SMUT OF BARLEY SHOWING VARIOUS STAGES IN THE DEVELOPMENT OF SMUTTED HEADS

Photographed by the Office of Cereal Investigations, United States Department of Agriculture

years. Infected grains are perfectly sound and cannot be distinguished from healthy ones except by a microscopic examination. On germination of the seed the mycelium of the fungus renews its growth and, as the plant develops, keeps pace with the growing tip of the stem, finally invading the flowers and the chaff and reducing them to a mass of smut. Infection of Alpha barley is largely of this type.

The second type of life history apparently differs from the first in that the smut spores instead of immediately germinating on the pistil of the barley flower, fall between the glumes and the kernel of the seed where they remain viable for at least a year. After the seed is planted and

sprouting begins, the smut spores send out germ tubes which may enter the growing barley seedling at any time before it appears above the ground. After infection, the fungus develops inside the plant in exactly the same way as it did in the case of flower infection. The six-rowed Tennessee winter barley becomes infected in this manner. In Fetherstone No. 7, a six-rowed barley, infection takes place in both ways.

Weather conditions exert a considerable influence on the amount of smut. Rains at flowering time wash the spores to the ground and thus reduce the chance of their reaching other heads. The most favorable temperature for infection by the fungus is higher than that for the best growth of the seedling so that late-planted spring barley often has a higher percentage of smut.

Control

When the fungus passes its period of dormancy in the mycelial stage inside of the embryo of the seed, some treatment must be applied which will kill it but which will cause as little injury as possible to the seed. Considering all varieties of barley, the hot-water treatment gives the best control of this smut. This treatment is the same as that described for loose smut of wheat (pages 12 to 13) with the exception that the grain is held in the last vat for thirteen minutes at 126°F. or for fifteen minutes at 125.6°F. A temperature of less than 125°F. will not kill the fungus and a temperature of more than 129°F. will injure the barley seed.

It has been found that soaking the seed in formaldehyde or in solutions of organic-mercury compounds will control this smut in six-rowed winter barley, and will reduce the amount of smut in certain six-rowed spring barleys, such as Fetherstone and Wisconsin Pedigree No. 5.

Formaldehyde treatment

The barley should be placed, after being cleaned, in a solution of formaldehyde made by diluting one pint of formaldehyde in forty gallons of water, being careful that all the barley is covered. It should be left there for ten minutes, after which the solution is drained off, the barley poured out in a pile, and covered for from ten to twelve hours with bags or blankets. The seed should then be spread out in a thin layer to dry.

Organic-mercury treatment

The following solution should be prepared in a non-metallic receptacle, such as a wooden barrel or an earthenware crock:

To each two and one-half gallons of water, one ounce of an organic-mercury compound, such as mercuric cyanide, or one of the several proprietary compounds, such as uspulun or semesan, should be added. Injury to certain seeds from the use of mercuric cyanide has been reported by

some investigators. The writer has never observed injury to barley seed from the use of this material.

The seed, after being cleaned, should be placed in this solution for one hour, care being taken to have the seed all covered. At the end of this period of soaking the solution should be drained off, and may be saved, as it can be used a second time. The barley should be immediately spread out in a thin layer and dried. Since these solutions and the treated seed are poisonous, they must not be fed to livestock. This treatment, in addition to controlling both loose and covered smuts of certain varieties of barley, causes a stimulation to all varieties, which may result in increased stands and yield. Loose smut of Alpha barley is not controlled by either the formaldehyde or the organic-mercury treatment.

COVERED SMUT OF BARLEY

(Caused by *Ustilago hordei*)

Except for the loose smut, the covered smut is the most destructive disease affecting barley. It usually occurs in about 50 per cent of the barley fields of this State and causes an average loss of about 1 per cent. This smut is restricted to barley.

FIGURE 26. COVERED SMUT OF BARLEY

Photographed by the Office of Cereal Investigations, United States Department of Agriculture

Symptoms

The first evidence of the covered smut is ordinarily not observed until about two weeks after blooming. The smutted heads, as a rule, appear later than the healthy ones. They often fail to emerge from the tops of the sheaths but, as the confined heads enlarge, they burst thru at the sides. Very rarely, do long streaks of smut appear on the top leaves. During the blooming period affected heads resemble healthy ones, but soon they appear to be smaller in size and have a darker hue. The smut mass which is coal-black to purplish black in color, with no tint of olive, replaces the kernels, the glumes, and the lower parts of the awns, but is covered by a tough silvery membrane which persists until harvest time (figure 26). The characters distinguishing the loose and covered smuts are given on page 51.

Cause

The fungus causing this smut is carried from crop to crop as spores adhering to the grain.

These spores become attached to the healthy kernels at threshing time when the smut masses are broken open. They germinate simultaneously with the barley seed and can infect the seedling only in the very young stage, that is, before it appears above ground. After infection the fungus develops inside of the plant and replaces the flowering parts at heading time.

Infection has been observed to take place most readily when the seeds germinate at a temperature of from 60° to 65°F., in a slightly acid to neutral soil, and in soil moderately high in moisture. Therefore, winter barley which is usually planted at higher temperatures than spring barley is more severely affected. Ordinarily this smut is more prevalent in the lower parts of fields where there is poor drainage.

Control

Sowing spring barley early in a well-drained and a well-prepared seedbed will reduce the amount of smut to some extent. The smut spores, however, which are carried on the outside of the seed, can be readily killed and the smut can be controlled by soaking the seed in an organic-mercury solution, as described for the loose smut of barley, or by treating the seed with formaldehyde, as described for the control of the loose smut of barley or the stinking smut of wheat.

STEM RUST OF BARLEY

(Caused by *Puccinia graminis*)

Stem rust (figure 27) in New York occurs more widely and is more destructive on barley than on any other cereal. It can be found in nearly every barley field in the State and causes a loss which, as in 1923, may average at least 1 per cent of the crop.

The reason for the greater severity of stem rust on barley is twofold. First, since barley is planted in the spring and thus matures later in the season than wheat and rye, the plants are exposed to infection over a longer period and the fungus can cause greater injury. Secondly, barley is attacked by forms of the rust occurring on wheat and rye, altho the rye form predominates.

Symptoms

The symptoms of stem rust of barley are the same as for this disease on wheat (pages 14 to 15).

Cause

The life histories of the two races of stem rust attacking barley are the same. Further details are given on pages 15 to 18.

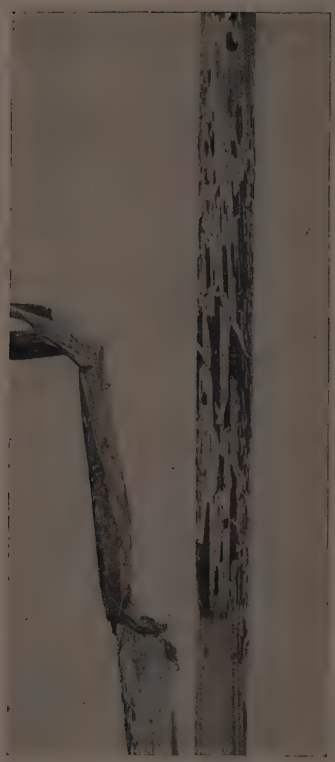

FIGURE 27. STEM RUST OF BARLEY

Control

Eradication of the common, or European, barberry will largely control this rust. Removal of barberry bushes in the vicinity of the field will effect some reduction of the rust, but more complete control requires that all bushes within a radius of two or three miles must be eradicated. The practicability of eradication depends upon the importance of barley to the grower, the percentage of loss caused by this rust, and the prevalence of barberry bushes.

The use of early maturing varieties and early sowing will aid, in that the plants may thus escape the disease.

LEAF, OR DWARF, RUST OF BARLEY

(Caused by *Puccinia simplex*)

Leaf, or dwarf, rust is likely to be of less importance than any other affecting the small grains in this State. Altho it is usually found in 75 per cent of the barley fields, but little damage is done. It occurs only on barley.

Symptoms

Leaf, or dwarf, rust is confined to the leaves, the stems, and the glumes, and is seldom observed in the fields before the barley plants head. Small, oval spots of a citron-yellow color are to be found scattered irregularly on both surfaces of the leaves. As the barley matures, the yellow spots are replaced by slate-colored patches which are usually confluent. It can be distinguished from the stem rust by the same characters as described under leaf rust of wheat.

Cause

The life history of this rust has not been worked out carefully. There is evidence, however, that the fungus is able to pass the winter and the summer in the red-rust, or uredinial, stage on volunteer and winter barley. In Europe, the teliospores, or winter spores, pass the winter on affected parts of the plant. Altho in Europe the aecial, or cluster-cup, stage occurs

in the spring on the Star of Bethlehem (Ornithogalum sp.), this stage has never been reported in America.

Control

The unimportance of this rust obviates the necessity for control measures.

SCAB, OR FUSARIUM BLIGHT, OF BARLEY

(Caused by *Gibberella saubinetii*)

Scab, or Fusarium blight, has never been observed to be causing any particular damage in New York. Usually in examining a large number of fields, not over one or two affected plants can be found any season.

Further details concerning this disease are given for wheat scab (pages 21 to 24).

TAKE-ALL OF BARLEY

(Caused by *Ophiobolus cariceti*)

While barley is known to be moderately susceptible to take-all, no infected plants have as yet been found in New York.

A more detailed discussion of this disease is given on pages 24 to 27.

STRIPE DISEASE OF BARLEY

(Caused by *Helminthosporium gramineum*)

Stripe is one of the most important and widespread diseases of barley. It is one of the very few cereal diseases in which all of the affected plants fail to produce any grain. Stripe occurs in more than one-half of the barley fields in New York and, altho it usually causes an average loss of less than 1 per cent, it has been observed in individual fields to cause a loss as high as 20 per cent. It is known to occur only on barley.

Symptoms

Altho the first evidences of infection are small pale spots in the young seedlings, these are seldom observed in the field, and the disease is not plainly evident until several weeks before the plants head. At this time from one to seven long yellowish stripes appear on each of the older leaves of all the stalks in a stool. The stripes usually extend from the base to the tip of the leaf and give it the appearance of "ribbon grass." Soon after the yellow stripes show, brown streaks, which may or may not be bordered by a yellow zone, appear in them. The tissue in the brown streaks soon dies, and this is followed by a longitudinal splitting of the blades. The growth of the diseased plants is stopped so that they rarely attain more than one-half their normal height. The head seldom becomes visible and always fails to emerge completely. Diseased plants die soon

after flowering time, crinkle, and are more or less inconspicuous at or just before the time of ripening of the healthy grain.

Cause

Stripe of barley is caused by a fungus which has a life history very much like that of the fungus causing loose smut of barley. Soon after the affected plants die, enormous numbers of spores (conidia) are produced on the dead foliage. These are carried by wind and other agencies to the floral parts of healthy plants where they contaminate or infect the new seed. When this inoculated seed germinates, the seedling tissues are infected immediately. After this the parasite grows with the host, maintaining itself near the growing point, so that the entire plant is ramified by the mycelium.

Control

The use of disease-free seed or the seed treatment, has been so successful in controlling stripe that these control measures have been the only ones usually recommended. The following treatment of the seed has also been found to be effective:

1. Soak the barley seed from one-half to one hour in a solution of mercuric cyanide or a proprietary material, such as uspulun or semesan. The strength of the solution should be three parts of the material to one thousand parts of water, that is, one ounce of the material to two and one-half gallons of water. The seed should be dried immediately after soaking and, as it is poisonous, the treated grain should not be fed to livestock.

2. The modified hot-water treatment used to control loose smut of barley will give practically complete control.

3. Stripe can also be greatly reduced by soaking barley seed for one hour in a solution of one pint of 40-per-cent formaldehyde in twenty gallons of water. The seed should be dried immediately after the soaking, since there is always danger of seed injury when using formaldehyde.

SPOT BLOTCH OF BARLEY

(Caused by *Helminthosporium sativum*)

The spot-blotch disease is known to occur in nearly every field of barley in New York. The annual loss in the State varies from 0.5 to 3 per cent. The spotting of the leaves is of only minor importance compared to the injury resulting from root rot and head blight.

The fungus causing spot blotch is the same as that causing the Helminthosporium disease of wheat and has the same host range, namely, wheat, barley, rye, oats, and several wild grasses. Manchuria barley is known to be resistant to this disease.

Symptoms

This disease affects all parts of the barley plant. The symptoms differ from those on wheat in that the leaves are the parts most conspicuously affected (figure 28).

FIGURE 28. SPOT BLOTCH OF BARLEY

Infected seedlings showing root rot, kernel discoloration, basal browning, and leaf lesions. (Photographed by the Office of Cereal Investigations, United States Department of Agriculture)

On the seedlings.— The use of affected seed usually results in the formation of chocolate-brown discolorations on the blade or sheath of the first leaf which becomes yellow and dies. An examination of the roots of an affected seedling shows many brown lesions and considerable rotting. The seedling may be killed.

On leaves and stems.— The disease is relatively inconspicuous until the plants begin to head. Characteristic spots first appear on the lower leaves. These have varying forms and are usually about one-tenth inch wide and from one-tenth to one-half inch long. They are dark brown in the center, the color fading gradually at the margins and blending into the green of the surrounding tissue. The center of these spots never appears netted as do the spots caused by the net-blotch disease of barley. The disease progresses from the older to the younger leaves, those severely spotted being killed. This killing of the leaves combined with the root rot causes the plant to ripen prematurely.

On the heads.— Numerous dark-brown spots may appear on the glumes and on the germ end of the diseased kernels.

Cause

The life history of the causal fungus is given under the discussion of Helminthosporium disease of wheat (pages 29 to 30).

Control

The methods used in controlling this disease in wheat also apply to its control in barley, that is, the use of clean seed, crop rotation, eradication of grass hosts, and the use of resistant varieties.

Seed treatment with organic-mercury solutions, as described for the control of stripe disease of barley, will kill the pathogene in many of the affected seeds.

NET BLOTCH OF BARLEY

(Caused by *Helminthosporium teres*)

Plants affected with net blotch have been found during the past several years in about one-half of the barley fields in New York. The loss caused by it has never been observed to be more than 0.5 per cent. It occurs only on barley.

Symptoms

The symptoms of net blotch are practically identical with those of spot blotch (pages 59 to 60) with the exception of the character of the leaf spots. The net-blotch spots are oblong, the older spots reaching a length of one inch. They differ from those of spot blotch in that they are surrounded by a narrow yellow zone and have an irregular distribution of the brown pigment in the spots. The brown pigment segregates into narrow lines, some running crosswise and some lengthwise of the leaf. As a result, a dark-brown netted pattern may be distinguished within the areas of diffused brown. This netted pattern can be more easily seen by transmitted light.

Cause

The life history of the fungus that causes this disease is essentially the same as that for the spot-blotch organism, the fungus passing the winter in affected seed and plant debris. The base of the barley plant is the first part to be infected. After gaining entrance to the plant, the fungus penetrates to the first leaf where many summer spores (conidia) are produced. These spores are then disseminated by wind and water to other leaves where they initiate new infections, resulting in the production of many more spores. Numerous cycles of infection with spore production may take place during a growing season, and every plant in a field and even in neighboring fields becomes diseased.

Control

The measures to be applied in the control of this disease are very much the same as for spot blotch. They consist of crop rotation, early sowing of spring barley, and the use of clean seed or seed which has been treated. Any of the treatments described for the control of stripe or spot blotch of barley or Helminthosporium of wheat, may be employed.

ANTHRACNOSE OF BARLEY

(Caused by *Colletotrichum graminicolum*)

Anthracnose is seldom observed in New York and is considered to be of very minor importance.

A more detailed discussion of this disease is given for anthracnose of wheat (pages 30 to 31).

BACTERIAL BLIGHT OF BARLEY

(Caused by *Bacterium translucens*)

Altho bacterial blight has not been found in New York, it is widespread in Ohio and westward, where it causes considerable loss. It is not known to affect any crop other than barley, but all types of this cereal may become diseased.

Symptoms

Bacterial blight usually affects the leaves, but in rare cases it may also occur on the stems and the glumes.

On the young leaves small water-soaked areas develop. Later these enlarge to yellowish or brownish, somewhat translucent blotches, or form irregular stripes which may extend the entire length of the leaf (figure 29). A bacterial exudate oozes from the lesions on the leaves. This exudate consists at first of milky drops which later become yellow and, when dry, flaky in appearance.

Lesions similar to those on the leaves may appear later on the glumes. Sometimes the enveloping sheath is glued together in such a manner as to prevent the emergence of the head, which may thus become bent and distorted. Some of the grains may be shrunken.

FIGURE 29. BACTERIAL BLIGHT OF BARLEY
Photographed by the Office of Cereal Investigations, United States Department of Agriculture

Cause

As the name indicates, this disease is caused by bacteria. The organism lives from year to year largely on diseased seed but may also pass the winter on the dead leaves and the stems of its host. The bacteria are carried to healthy plants by rain, dew, and insects, and enter the tissues thru the stomates. Within the plant the bacteria are found between the plant cells, where they increase greatly in numbers.

The cycle of multiplication, dissemination, and infection may be repeated many times before maturity of the grain. The bacteria are confined to the leaf or glume which is attacked, that is to say, they do not penetrate thruout the plant.

Control

As the bacteria are disseminated with the grain, one should avoid using seed from fields or localities in which the disease is severe. When seed from an unknown or questionable source must be used, disinfection with formaldehyde may reduce the danger of the disease. Treat as for smut, except that the seed should be soaked in the solution (one pint of formaldehyde to forty gallons of water) for from one to two hours.

POWDERY MILDEW OF BARLEY

(Caused by *Erysiphe graminis*)

Powdery mildew is present in most of the barley fields in New York. Its prevalence is greatly influenced by the cultural methods. Where crop rotation is practiced, there is seldom more than from a trace to 5 per cent of mildew present, but where barley is repeatedly grown on the same land, an infection of from 80 to 100 per cent of the plants may be expected. Since practically all barley in New York is grown in a rotation, the loss due to this disease is negligible.

The symptoms, cause, and control of powdery mildew are the same as those given for this disease on wheat (pages 34 to 36).

ERGOT OF BARLEY

(Caused by *Claviceps purpurea*)

Under the conditions existing in this State, barley seems to be more resistant to ergot than is wheat. During the past few years only one infected head of barley has come to the attention of the writer.

For further details on symptoms, cause, and control, refer to the discussion of this disease on rye (pages 69 to 71).

RYE

STEM SMUT OF RYE

(Caused by *Urocystis occulta*)

The stem smut of rye, altho by no means the most destructive disease of this crop in New York, is, nevertheless, of some importance in the Hudson Valley where an average of nearly 1 per cent of affected plants occurs. The annual loss in the State is less than 0.25 per cent. This smut occurs only on rye.

Symptoms

All of the above-ground parts of the rye plant are affected.

The first symptom of the disease appears when the stalks are from 6 to 12 inches in height. It consists of a darker green color and distortion of the affected leaves and stems. Before the plants head, the smut appears as long, narrow, parallel lead-gray stripes beneath the epidermis. Later the epidermis ruptures, exposing the dark smut mass, and the affected stem and leaves split and twist (figure 30). The smutted plants are usually stunted and distorted, and seldom produce heads. Such plants are readily overlooked at harvest time unless there is a very heavy infection in the field.

FIGURE 30, STEM SMUT OF RYE
Photographed by the Office of Cereal Investigations, United States Department of Agriculture

Cause

Rye smut is caused by a fungus that produces its spores in the long stripes on the above-ground parts of the plants. In threshing, these spores become lodged on the surface of the seed and are carried to the soil. When such seed is sown, even in smut-free soil, or when clean seed is planted in infested soil, enough of the smut spores may germinate at about the same time the seed germinates, to infect the young seedlings before they reach the surface of the ground. The parasite extends its small thread-like growths upward thru the plant. Vast numbers of smut spores are produced in the lead-colored stripes.

These smut spores have been reported to live for twelve years upon the surface of stored grain. They can also live for several years in dry soil but under field conditions most of them will germinate and die within a year after their formation.

Control

Since a rye crop may become smutty by the use of contaminated seed or by the planting of clean seed in smutty soil, these sources of infection must be eliminated if the disease is to be controlled. The smut spores on the seed can be killed by the formaldehyde or the copper-carbonate-dust treatments. The smut spores in the soil will be killed if a three- or four-years rotation is practiced. The copper-carbonate-dust treatment of the seed apparently gives fair protection from infection by the spores in the soil as well as those on the seed.

Formaldehyde treatment

It must be remembered that the formaldehyde treatment kills only the smut spores on the seed at the time of treatment and does not protect the seed from subsequent infection. If this treatment is used, crop rotation should also be practiced. The method of treating rye to control this smut is the same as that described for the treatment of wheat to control stinking smut, with the exception that there are no smut balls to be skimmed off (page 10).

Copper-carbonate-dust treatment

Copper-carbonate dust is applied in the same way as that described for treating wheat to prevent stinking smut, except that from three to four ounces of the copper-carbonate dust should be used to each bushel of rye.

LOOSE SMUT OF RYE

(Caused by *Ustilago tritici*)

Loose smut (figure 31) is of no economic importance since it usually occurs only on volunteer rye growing in a field planted to wheat. It has been observed by the writer but twice

FIGURE 31. LOOSE SMUT OF RYE

in this State. This is the common loose smut of wheat to which rye appears to be highly resistant.

A discussion of loose smut of wheat is given on pages 10 to 13.

STINKING SMUT, OR BUNT, OF RYE

(Caused by *Tilletia tritici*)

The stinking smut of rye has been reported but once in New York. It has been reported as occurring in the western part of the United States. Rye is very resistant to it, and never more than a few infected heads have been found in a field. The same fungus causes stinking smut of wheat in the West. The stinking smut in wheat commonly found in this State is caused by another species of smut fungus. Whether this fungus ever attacks rye is unknown.

For symptoms, cause, and control of this disease, refer to stinking smut of wheat (pages 3 to 10).

STEM RUST OF RYE

(Caused by *Puccinia graminis*)

In New York, rye matures sufficiently early to escape most of the injury from stem rust unless it is located near barberry bushes. Therefore, the loss from stem rust in rye is usually negligible. Even at its worst, never more than 30 per cent of rusted plants has been found in any one field.

In addition to rye, this form of stem rust occurs on barley, quack grass, and meadow-fescue grass.

Symptoms

The symptoms of this disease are the same as those described for stem rust on wheat, pages 14 to 15.

Cause

The life history of the stem-rust fungus is the same as that for the wheat form. The race occurring on rye is the most common in this State of any of those attacking cereals. This seems to be due to prevalence of its grass hosts, mainly quack and meadow-fescue grass, which are more often located around the barberry bushes than is rye. These grasses greatly increase the amount of the black-rust (telial) material near the bushes, and this results in the barberries having a heavier infection with this form than with any other form of stem rust. Besides, these same grasses act as multiplying stations for the rust in going from the common barberry bushes to rye or barley.

Control

Since rye usually escapes this rust, there is no need ordinarily in being concerned with its control. If the rust becomes severe in any area, it is

likely to be caused by the presence near-by of common barberry bushes, which should be located immediately and destroyed.

LEAF RUST OF RYE

(Caused by *Puccinia dispersa*)

During the past five years leaf rust of rye has caused a greater loss to this crop than any other disease. It has been found every year in all the rye fields in the State and results in an annual loss which averages from 1 to 5 per cent according to weather conditions prevailing during the spring.

Rye is the only cereal affected by this rust. Several species of borages (Anchusa sp.) serve as alternate hosts for the causal fungus.

Symptoms

The red-rust, or uredinial, stage of this rust can be found on rye thruout the year. It is confined largely to the leaves as small oval spots of a chocolate to reddish brown color. On the stems these rust pustules or uredinia appear somewhat like those of stem rust but are less elongated. As the rye plant reaches maturity, the brown spots are replaced by slate-colored ones which are covered by the epidermis. This constitutes the black, or telial, stage of the rust. The presence of the epidermis over the telia and the more common occurrence of the red-rust stage on the leaves constitute the principal characters by which this disease may be distinguished from the stem rust.

Cause

This rust is caused by a fungus which is able to propagate itself from year to year by repeated generations of the red-rust spores. These spores may be blown for long distances, and under the proper weather conditions, are able to infect rye plants. During April, May, and June, the cycle of spore production, dissemination, and infection may be repeated from ten to fifteen times, thus making it possible for a few overwintering red spores to increase their number, so that they cause a local rust epiphytotic. As the plant matures, black two-celled teliospores replace the red urediniospores. Germination of these black spores may take place either immediately or it may be delayed until spring. On germination, these spores bring about an infection of certain borages (Anchusa sp.). This infection results in the formation of yellow-colored spots on the leaves of these plants. In these spots tiny cup-like depressions are developed in which light-yellow aeciospores are produced. These on dissemination to the rye plants may bring about the red-rust stage. This cluster-cup, or aecial, stage is apparently rare in the United States.

Control

At the present time, there is no very satisfactory control measure known.

SCAB, OR FUSARIUM BLIGHT, OF RYE

(Caused by *Gibberella saubinetii*)

During most years scab, or Fusarium blight, is not of any economic importance on rye, since only a few plants with seedling blight, or scab, may be found in an occasional field. In an exceptional year like 1919, when moist warm weather prevails during the blossoming period, more than 1 per cent of the heads, on an average, may be scabbed, and the loss from the root and head blight combined may run well above this figure.

Rye is not so susceptible to this disease as is wheat and is also more resistant than barley and oats.

For further details regarding symptoms, cause, and control of this disease, refer to the discussion of wheat scab (pages 21 to 24).

TAKE-ALL OF RYE

(Caused by *Ophiobolus cariceti*)

Up to the present time take-all has been found in only one rye field and on volunteer plants growing in badly infested wheat fields. Rye apparently is much more resistant to this disease than is wheat and the loss to the rye crop from it is negligible.

Symptoms

Rye shows no yellowing until after flowering and, therefore, exhibits little or no stunting and only a moderate shriveling of the kernels.

Further details concerning this disease are given for take-all of wheat (pages 24 to 27).

HELMINTHOSPORIUM DISEASE OF RYE

(Caused by *Helminthosporium sativum*)

Helminthosporium disease is found rather commonly on rye in New York but apparently is not so serious as on wheat.

For symptoms, cause, and control of this disease, refer to the discussion of Helminthosporium disease of wheat (pages 28 to 30).

ANTHRACNOSE OF RYE

(Caused by *Colletotrichum graminicolum*)

Anthracnose is present in practically every rye field in New York and usually causes an average loss of about 1 per cent. The loss may be greater during seasons favorable for the development of the parasite.

Symptoms

The symptoms of the disease are the same as those described for wheat, with the exception that the rye plants are sometimes stunted and blighted,

appearing almost colorless, and that the entire portion of the head above the point of infection may be killed. All the kernels in the affected portions usually are worthless.

The cause, control, and host range of this disease are the same as those for anthracnose of wheat, pages 30 to 31.

POWDERY MILDEW OF RYE

(Caused by *Erysiphe graminis*)

Powdery mildew occurs in most of the rye fields in New York. The amount present is, on the average, less than 5 per cent, and fields are seldom observed with more than 20 per cent of the plants affected. Rye seems to be more resistant to powdery mildew than is wheat and it is probable that the loss due to this disease is less than 0.5 per cent.

Refer to the discussion of powdery mildew of wheat for the symptoms, cause, and control of this disease, pages 34 to 36.

ERGOT OF RYE

(Caused by *Claviceps purpurea*)

The importance of ergot is due, not so much to its causing a reduction in the yield of the rye crop, but rather to the danger to animals from eating the ergots developed by the fungus. Such serious diseases of horses, cattle, and even humans, as ergotism, gangrene, and abortion, are caused by eating quantities of grain, straw, or flour containing ergot. Severe cases of these diseases were reported in Orange County, New York, in 1820.

Ergot is usually present in about one-third of the rye fields in New York. During an average year, it causes a very small loss to the rye crop but, under favorable conditions for the disease, a loss of from 5 to 10 per cent has been observed in some fields.

Rye, meadow fescue, quack, timothy, and blue grasses are susceptible to this disease. Wheat and barley are only slightly susceptible, while oats are rarely affected.

Symptoms

This disease affects only the head of the various susceptible plants. The first evidence of the disease is to be observed soon after the first heads have come into flower. It consists of a yellowish, sticky fluid, "honeydew," which oozes from certain flowers. This fluid may cover the entire head which becomes discolored or even black from dust that adheres to it.

The characteristic sign of the disease is the replacement of one or more kernels in a head with the purplish black, horn-like sclerotial bodies (figure 20), which are themselves called "ergot." They are somewhat angular

and curved and vary in size from that of a rye kernel to a length of one and one-half inches.

This disease causes many empty florets and blackened grains, and also stunts the heads so that they are shorter in length and lighter in weight than healthy ones.

Cause

The fungus causing this disease passes the winter as ergot bodies (sclerotia) either in the field or with the grain in the bin. The following spring several tiny mushroom-like bodies, called stromata, are produced from the sclerotia on or slightly beneath the surface of the soil. These are about as thick as the lead of a pencil and have a globose head one-fifth inch in diameter. In the surface of this head, hundreds of spore sacs (perithecia) are developed in which ascospores are contained. These spores are forcibly ejected, under favorable conditions, during a period of from two to four months. They are carried by wind to the heads of rye and, at flowering time, they bring about an infection of the young flower ovaries. The ovaries within one to two weeks after infection start exuding the honeydew. This fluid contains millions of summer spores (conidia) which are widely disseminated by insects attracted to the honeydew, by rain, and by the honeydew-laden heads coming in contact with healthy ones. The infected ovaries are replaced by fungous mycelium, which in turn develops to form the ergot body, or sclerotium. The ergots may either fall to the ground when mature or be carried with the seed to a new field. They do not germinate to form the knob-like fruiting body until the following spring and usually do not live for more than one year.

Control

A rotation of two or three years should be practiced, since many ergot-bodies drop from the infected rye heads before harvest. These would cause infection if wheat or barley, and especially if rye, were planted again on the same field.

It is obvious that a successful control measure must include the removal of the ergot bodies from the seed. Since these vary greatly in size, only the larger ones can be removed by the use of a fanning mill. They are, however, a little lighter than sound rye kernels so that they can be separated by the use of a salt-brine solution. This can be done as follows:

A brine of about 20-per-cent strength (forty pounds of common salt to twenty-five gallons of water) is placed in a tub or barrel. When the salt solution is ready, the rye is slowly poured in by one person, while at the same time another stirs the solution vigorously. The sound seed will sink to the bottom while the ergot bodies and the light and shriveled grains will float to the top where they can be skimmed off and discarded.

If, on adding the grain to the solution, the ergots do not rise to the top, more salt is needed. After all the ergots are skimmed off, the salt solution is drained into another receptacle, as it can be used again and again. The rye seed is rinsed immediately with plenty of fresh water to remove the salt and is spread out to dry. Care must always be taken to wash the rye seed thoroly after treatment. Otherwise the germination of the seed will be lowered.

On account of the short life of the ergot bodies, two- or three-year -old seed, even if badly infected, can be planted without treatment.

Since several wild grasses, like quack and meadow fescue, are usually severely attacked, they should be removed from the fence rows and waste places near the fields in order to prevent the disease from spreading to the rye.

NEMATODE DISEASE OF RYE

(Caused by *Tylenchus tritici*)

Nematode disease of rye is not known to occur in New York. The symptoms, cause, and control of this disease are the same as those for nematode disease of wheat (pages 39 to 40).